DOE/FE-0114

Comprehensive Report to Congress: Proposals Received in Response to the Innovative Clean Coal Technology Program Opportunity Notice

October 1988

U.S. Department of Energy
Assistant Secretary for Fossil Energy
Washington, DC 20585

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EXHIBITS

I. Executive Summary

This report is a comprehensive overview of the projects selected and all proposals received in response to the Program Opportunity Notice for Innovative Clean Coal Technology Demonstration Projects (solicitation number DE-PS01-88FE61530) issued by the U.S. Department of Energy on February 22, 1988. Through this Program Opportunity Notice (PON), the Department of Energy (DOE) solicited proposals to conduct cost-shared innovative clean coal technology projects to demonstrate technologies that are capable of being commercialized in the 1990s, that are more cost-effective than current technologies, and that are capable of achieving significant reduction of sulfur dioxide (SO_2) and/or nitrogen oxide (NO_x) emissions from existing coal-burning facilities, particularly those that may contribute to transboundary and interstate air pollution.

This Innovative Clean Coal Technology (ICCT) PON is the second of a series of solicitations being conducted by DOE as part of the broader Clean Coal Technology Demonstration Program. This is a technology development program jointly funded by government and industry. It will take the best and most promising of the advanced, clean coal technologies and, over the next decade, will move them into the commercial marketplace through demonstration. These demonstrations will be at a scale large enough to generate the data (from design, construction, and operation) necessary for the private sector to judge their commercial potential and to make informed commercial decisions.

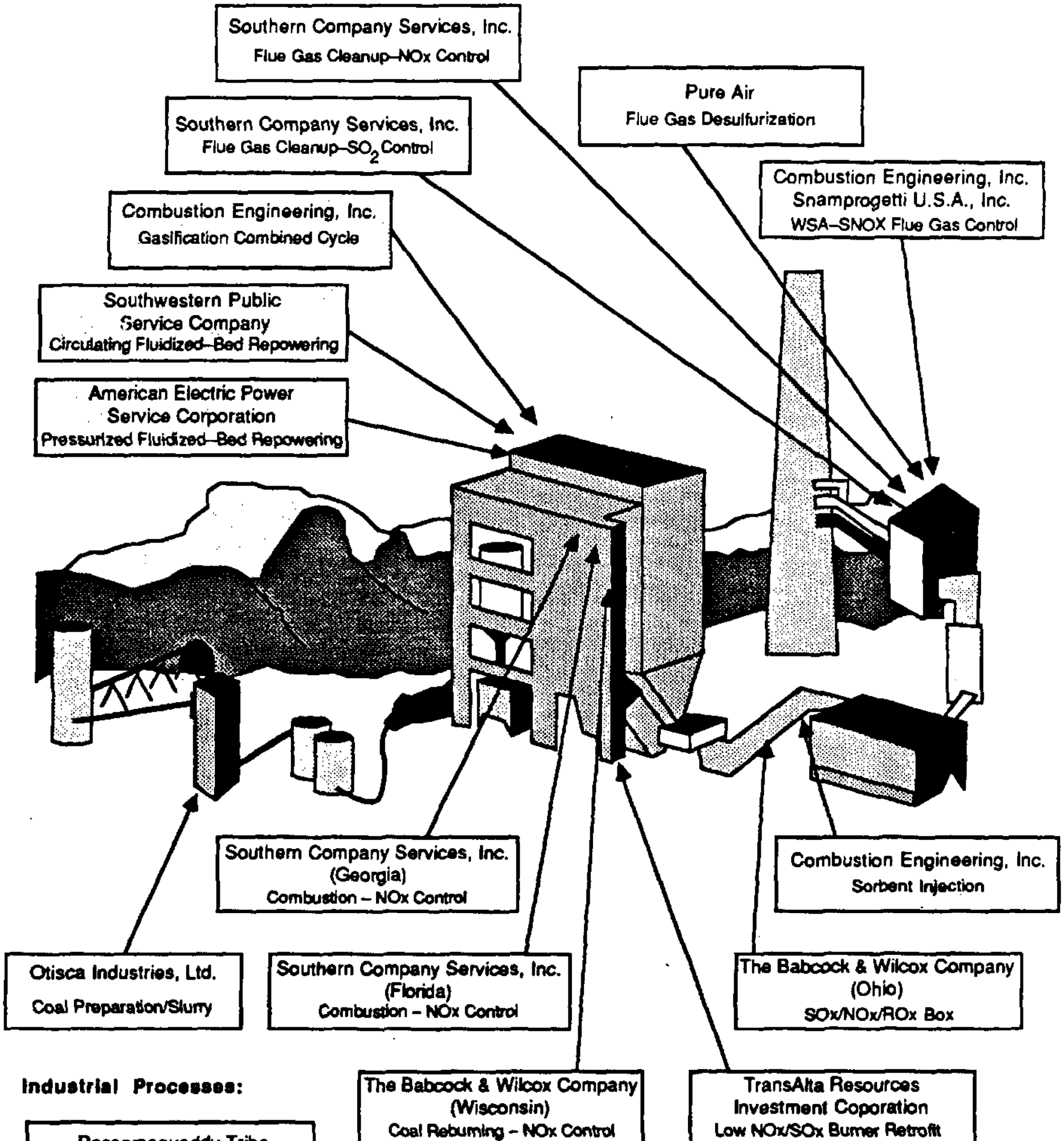
CLEAN COAL TECHNOLOGY DEMONSTRATION PROGRAM

The Clean Coal Technology Demonstration Program is aimed at selecting advanced coal based technologies that have been proven to work at smaller scales and moving them into large-scale demonstrations, where their market viability and commercial-scale performance can be assessed. Candidate projects are selected for direct financial assistance for a specific period of design, construction, and operation. The project sponsor, who must contribute at least half the costs of the demonstration effort, is then responsible for commercialization of the technology. The government then receives revenues based on the sale or licensing of the demonstration technologies over a period of years to recoup some of the taxpayers' investment.

The cost-shared projects will demonstrate the feasibility of future commercial applications of a new generation of clean coal technologies. These projects include the design, construction, and operation of the demonstration facilities. Their purpose is to provide sufficient technical, economic, environmental, health, safety, and operational information to enable the private sector to make rational commercialization decisions.

The program currently consists of two major parts: the Clean Coal Technology I (CCT-I) Demonstration Program and the Innovative Clean Coal Technology (ICCT) Demonstration Program. Each corresponds to a solicitation for industry proposed, cost-shared demonstration projects. CCT-I is oriented toward a wide range of technologies for the full spectrum of U.S. energy markets. A total of 11 projects comprise CCT-I. The ICCT will demonstrate innovative concepts for reducing coal-burning emissions thought to cause acid rain. A total of 16 projects have been selected for award under the ICCT solicitation--the subject of this report.

Exhibit 1. APPLICABILITY OF ICCT PROJECTS SELECTED



Industrial Processes:

Passamaquoddy Tribe
Scrubbing System for Cement Kilns

Bethlehem Steel Corporation
Coke Oven Cleaning

The shaded blocks correspond to those *"repowering"* projects that replace major sections of the existing power plant.

CLEAN COAL TECHNOLOGIES

Clean coal technologies, compared to current technologies, have the potential to increase the efficiency at which coal is converted to usable energy, to minimize any environmental impact associated with the use of coal, and to reduce substantially the costs at which this energy is made available.

Current technologies achieve emissions control with some trade-offs. For example, flue gas desulfurization (scrubbers) can remove 90 percent of the sulfur pollutants from the combustion gases of coal; but scrubbers are very costly and have virtually no effect on NO_x emissions. Scrubbers also consume a portion of the power plant's energy, thereby reducing the efficiency and raising the cost of electricity. Moreover, scrubbers produce massive amounts of waste that are difficult to handle and are environmentally damaging if not disposed of properly. Conventional coal cleaning has a limited ability to remove sulfur impurities, typically only 10-30 percent of the total sulfur in coal, and therefore cannot achieve the more stringent Clean Air Act standards by itself. Coal switching (from high-sulfur to low-sulfur coal) cannot be used to meet the new standards and, even if applied to existing plants, often results in diminished boiler performance and increased costs (because low-sulfur coal is typically more expensive than high-sulfur coal).

Advanced clean coal technologies, however, offer the opportunity to produce usable *energy at costs much lower than current technology. Of equal importance, clean coal* technologies open the door to a future of sustained reductions in the acid rain precursors SO_2 and NO_x while enabling greater use of a vast energy resource--coal.

Among these advanced clean coal technologies are concepts such as (1) fuel upgrading, including coal cleaning and upgrading and coal liquefaction; (2) SO_2 and NO_x emissions control, including advanced flue gas desulfurization, sorbent injection, low NO_x combustion, post-combustion NO_x control, and combined SO_2/NO_x control; and (3) advanced combustion and gasification, including atmospheric fluidized-bed combustion, pressurized fluidized-bed combustion, slagging combustion, and integrated gasification combined-cycle. The successful outcome of the Clean Coal Technology Demonstration Program would result in the development and commercialization of a new suite of advanced clean coal technologies.

The common thread running through the many advanced clean coal concepts is the ability to use a variety. of domestic coals more efficiently while better protecting the environment. Several of these concepts have the added advantage of boosting an existing power plant's electrical output, possibly forestalling expensive investment in new power generating capacity. Many can be added in modular fashion to match more closely a utility's supply and demand requirements. Together, advanced clean coal technologies can offer opportunities for significantly reducing, or perhaps eliminating, the threat of acid rain damage in the future, while at the same time create the capability to solve the anticipated problems of meeting requirements for increased power production capacity.

The selected ICCT projects and their applicability to existing power plants are shown in *Exhibit 1. This diagram depicts the different points in coal's fuel chain where the* selected projects would be used. The selected projects apply to all three stages of the fuel chain: (1) pre-combustion coal cleaning, (2) the combustion process itself, and (3) post-combustion flue gas cleaning.

CONTENTS OF THIS REPORT

The subject of this *Comprehensive Report to Congress* is the response to the ICCT PON and the projects selected for award. Chapter II is an overview of the Clean Coal Technology Demonstration Program and the events which have shaped the direction and purpose of the program and the solicitations for proposed projects. Chapter III presents the ICCT projects selected for award. It also contains an overview of the ICCT PON, a summary of the proposal evaluation process and a description of selected projects. Highlighted is an estimate of the collective SO_2 and NO_x emissions reductions that might be achieved by the selected projects.

Chapter IV presents key information on all 55 proposals submitted in response to the ICCT PON. A series of tables shows the major characteristics of the proposals, including proposed technical approaches, project size and duration, geographic location, sulfur content of coals proposed for utilization, and environmental and commercial characteristics of the proposed technologies.

The environmental considerations which are an integral part of the Innovative Clean Coal Technology Demonstration Program are explained in Chapter V. It outlines the strategy for addressing the requirements of the National Environmental Policy Act (NEPA) as well as the strategy for monitoring and documenting the environmental performance of the demonstration projects during implementation.

Appendix A contains technical descriptions of clean coal technologies that are commercially available as well as those under development in the public and private sectors. Appendix B contains additional project information about each of the 55 proposals submitted.

II. Events Leading to the ICCT Solicitation

Through the Clean Coal Technology Demonstration Program, DOE is conducting the following activities:

- Soliciting expressions of interest from industry for emerging clean coal technology projects
- Soliciting, selecting, and negotiating government-industry cost-shared projects, as funds are made available by Congress
- Assuring that the projects provide useful technical, environmental, operational, performance, and economic data to reduce the uncertainties of subsequent commercial scale deployment of the technology
- Developing a combined technical, engineering, and environmental knowledge base from which to make sound policy decisions relating to future clean coal technology initiatives and environmental issues and to provide the public with the information it needs to form a national consensus on the control of pollutants that may contribute to the formation of acid rain
- Providing an adequate technology transfer mechanism to assure that the private sector has the necessary access to the data on clean coal technologies
- Improving the regulatory and institutional climate to encourage deployment of demonstrated clean coal technologies into the marketplace at a pace consistent with free market decisions
- Fostering an understanding of the Clean Coal Technology Demonstration Program and its projects and the benefits to be derived from the demonstrations and subsequent deployment of these projects, by working with other federal agencies, states, and international and private organizations.

A series of solicitations for proposed demonstration projects are being issued. The first was CCT-I, which resulted in the selection of 11 demonstration projects. The second was ICCT. This chapter summarizes the key events which helped to shape the ICCT solicitation.

CCT-I SOLICITATION

The Clean Coal Technology I Demonstration Program, or CCT-I, had its genesis in August 1984 when work commenced on a solicitation for informational proposals and statements of interest. That "Section 321" Program Announcement, as it became known from the implementing section of Public Law No. 98-473,[1] was published in the *Federal Register* on November 27, 1984.[2] The objective, as stated in the announcement, was:

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[1] Pub. L. No. 98-473, House Joint Resolution 648, Making Continuing Appropriations for Fiscal Year 1985. Signed into law on October 12, 1984.

[2] "Program Announcement: Information Regarding Emerging Clean Coal Technologies," published in 49 *Federal Register* 229 (46696), November 27, 1984.

> ... to request Statements of Interest and Information Proposals from the [private] sector for information regarding emerging clean coal technologies to allow for the Departmental submission of a report to Congress ... which:
>
> - Analyzes the information contained in such Statement of Interest and [Informational] Proposals,
>
> - Assesses the potential usefulness of each emerging clean coal technology for which a Statement of Interest or Informational Proposal has been received, and
>
> - Identifies the extent to which Federal incentives, including financial assistance, will accelerate the commercial availability of these technologies.

This first foray into surveying the private sector for eligible demonstration projects resulted in 175 responses distributed among 13 technology categories and worth more than $8 billion in total.[3]

On December 19, 1985, Public Law No. 99-190 was enacted; among other things, it provided funds "... for the purpose of conducting cost-shared Clean Coal Technology projects for the construction and operation of facilities to demonstrate the feasibility for future commercial applications of such technology ..." and authorized DOE to conduct the first solicitation for cost-shared CCT projects.[4]

The Clean Coal Technology PON was issued on February 17, 1986, and contained guidelines stating that submissions must (1) be open to all market applications of clean coal technology that apply to any segment of the U.S. coal resource base, including utilities, industry (including steel and iron ore processing), commercial and residential markets, and transportation; (2) be open to both new and retrofit applications whether intended to displace oil and natural gas or to use coal more cleanly, efficiently, or economically than presently available technology; and (3) consist of industry projects, with financial assistance available from the government at levels up to 50 percent of project cost.

By April 18, 1986, the closing date, proposers had submitted 51 candidates for CCT-I demonstration projects. On July 25, 1986, DOE named 9 projects as its initial choices and on August 21, 1986, submitted a report to Congress on the solicitation.[5]

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[3] *Report to Congress on Emerging Clean Coal Technologies*, Report No. DOE/S-0034, U.S. Department of Energy, May 1985; and *Supplemental Report to Congress on Emerging Clean Coal Technologies*, Report No. DOE/MC/22121-1, U.S. Department of Energy, August 1985.

[4] Pub. L. No. 99-190, An Act Making Appropriations for the Department of the Interior and Related Agencies for the Fiscal Year Ending September 30, 1986, and for Other Purposes, signed into law on December 19, 1985.

[5] *Comprehensive Report to Congress on Proposals Received in Response to the Clean Coal Technology Program Opportunity Notice*, Report No. DOE/FE-0070, U.S. Department of Energy, August 1986.

On October 24, 1986, DOE submitted a second report to Congress assessing the relationship between CCT-I projects and the recommendations of the Special Envoys on Acid Rain.[6]

Fact-finding and negotiation activity with each industrial participant began immediately after selection. By the end of September 1987, two sponsors withdrew their proposals from further consideration. The funds made available by these withdrawals were used to select additional projects from the list of proposals identified in the July 25, 1986, Addendum to the Clean Coal Technology Selection Statement. On October 7, 1987, DOE selected 4 projects, bringing the total number of CCT-I projects to 11.[7]

By the end of October 1988, cooperative agreements had been executed for 9 of the 11 projects. In aggregate, the cost-sharing ratio for these 9 projects is 68.5 percent by the industrial participants and 31.5 percent by DOE. The funding ratio represents a commitment of $589.5 million by industry and $271.0 million by the federal government. (It should be noted that the participants will repay the government its contribution through recoupment provisions contained in the agreements.) Thus, the near-term investment of $271.0 million by the federal government is stimulating over $860.5 million of development efforts through the 9 projects with executed cooperative agreements.

Assuming the cooperative agreements for the remaining two CCT-I projects are executed, this will fully commit the remainder of the federal funds appropriated for CCT-I. The government will have leveraged its investment of $387.2 million to initiate and sustain over $1.2 billion of development support for the demonstration of clean coal technologies.

SECOND INFORMATIONAL SOLICITATION

In Public Law Nos. 99-500 and 99-591[8] passed in October 1986, Congress again directed DOE to solicit statements of interest and informational proposals as to the level of interest of potential industrial participants in another solicitation, "Emerging Clean Coal Technologies Capable of Retrofitting, Repowering, or Modernizing Existing Facilities," and meet the cost-sharing criteria established for CCT-I. DOE issued the Program Announcement in November 1986.[9] By the closing date, January 12, 1987, DOE had received from industry 139 proposals valued at over $5 billion. In accordance with congressional directives contained in Public Law No. 99-500, DOE submitted to Congress, on March 6, 1987, a summary report of statements of interest and informational proposals received and, on May 12, 1987, a second report analyzing the information contained in the submittals and assessing the potential usefulness and commercial viability

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[6] *Report to Congress on the Relationship between Projects Selected for the Clean Coal Technology Program and the Recommendations of the Joint Report of the Special Envoys on Acid Rain*, Report No. DOE/FE-0072, U.S. Department of Energy, October 1986.

[7] Progress on CCT-I was reported in *Clean Coal Technology Demonstration Program: Annual Report to Congress (As of December 31, 1987)*, Report No. DOE/FE-0107.

[8] The CCT provisions of Pub. L. Nos. 99-500 and 99-591 are identical. The former was presented to the President on October 17, 1986, as an enrolled resolution (H.J. Res. 738, Joint Resolution Making Continuing Appropriations for Fiscal Year 1987, and for Other Purposes), and was signed into law on October 18.

[9] Published in 51 *Federal Register* 218 (41060-41062), November 12, 1986.

of each emerging technology.[10] This informational solicitation indicated that industry was prepared to participate in a joint government-industry clean coal technology program oriented toward existing coal-burning facilities.

SPECIAL ENVOYS ON ACID RAIN

In March 1985 the President appointed Drew Lewis to be the U.S. Special Envoy on Acid Rain, and, at the same time, Prime Minister Brian Mulroney apppointed William Davis as the Canadian Special Envoy. The Special Envoys were charged with the responsibility to assess the international environmental problems associated with transboundary air pollution, and then recommend actions that would solve them.

In January 1986, the Envoys presented their findings and recommendations.[11] Beyond their recognition of the international nature of acid rain, the Envoys made three key recommendations:

- The initiation of a 5-year, $5-billion program in the United States for commercial demonstration of control technology projects recommended by industry and jointly funded by government and industry
- A commitment to ongoing cooperative activities, including bilateral consultations and information exchange
- A greater emphasis on carrying out research essential to resolving transboundary acid rain issues.

Because the technology demonstration program was meant as part of a long-term response to the transboundary acid rain problem, the Envoys also recommended specific criteria for the evaluation of prospective projects.

In March 1986, the President endorsed the Special Envoys' recommendations. His endorsement set into motion a year-long effort within DOE to develop an expanded clean coal technology program that would build on the initial effort, reflect ongoing state and privately initiated efforts, and be fashioned, as fully as practicable, from the guidelines recommended by the Special Envoys.

By March 1987, DOE had completed its initial selection of CCT-I projects and had submitted its report to Congress on the second informational solicitation, "Emerging Clean Coal Technologies Capable of Retrofitting, Repowering, and Modernizing Existing Facilities." DOE also had completed an analysis of the relationship between the projects

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[10] *Summary Report to Congress on Emerging Clean Coal Technologies Capable of Retrofitting, Repowering, or Modernizing Existing Facilities*, Report No. DOE/FE-0082, U.S. Department of Energy, March 1987; and *Second Report to Congress on Emerging Clean Coal Technologies Capable of Retrofitting, Repowering, or Modernizing Existing Facilities*, Report No. DOE/FE-0086, U.S. Department of Energy, May 1987.

[11] *Joint Report of the Special Envoys on Acid Rain*, January 1986.

selected for CCT-I and the recommendations of the Special Envoys.[12] Furthermore DOE had finished an inventory of private and state clean coal technology initiatives.[13]

PRESIDENT'S INITIATIVE

On March 18, 1987, the President announced his decision to commission a major expansion of the Clean Coal Technology Demonstration Program. He directed that three major steps be taken:

- The first was to seek the full amount of the federal government's share of the funding recommended by the Special Envoys--$2.5 billion--for demonstrating innovative control technology over a 5-year period, provided that appropriate projects were proposed and that industry would invest an equal or greater amount over this period to stimulate deployment of the advanced clean coal technologies.

- The second step was to direct the Secretary of Energy to establish an advisory panel (which became the Innovative Control Technology Advisory Panel, or ICTAP) to advise the Secretary on funding and criteria for selecting innovative control technology projects, using as fully as practicable the criteria recommended by the Special Envoys.

- The third step was to request that the Task Force on Regulatory Relief, chaired by the Vice President, review federal and state economic and regulatory programs to identify opportunities for addressing environmental concerns under existing laws.

The President's decision recognized four important factors: (1) the need to strengthen the cooperative effort between the United States and Canada in reducing emissions associated with acid rain; (2) the increasing importance of domestic energy resources, particularly in light of renewed threats to energy security caused by the upward trend in oil imports; (3) the potential of a serious gap developing in the 1990s between economic growth and the demand it will create for new electrical power, and the ability of the U.S. utility industry to supply it reliably and economically; and (4) the opportunity to establish the United States as the clear technological leader in world markets in terms of new, coal-based, environmentally clean energy technology.

INNOVATIVE CONTROL TECHNOLOGY ADVISORY PANEL

In response to the President's March 18, 1987, directive to establish an advisory body, DOE chartered the Innovative Control Technology Advisory Panel on April 27, 1987.[14] Members of ICTAP include senior representatives of several federal agencies (including

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[12] *Report to Congress on the Relationship between Projects Selected for the Clean Coal Technology Program and the Recommendations of the Joint Report of the Special Envoys on Acid Rain*, Report No. DOE/FE-0072, U.S. Department of Energy, October 1986.

[13] *America's Clean Coal Commitment*, Report No. DOE/FE-0083, U.S. Department of Energy, February 1987.

[14] ICTAP was established under provision of the Federal Advisory Committee Act, Pub. L. No. 92-463.

the Environmental Protection Agency), representatives from a cross-section of affected states, and representatives of private sector and citizen groups, such as producers and users of coal, environmental groups, unions, and the research community. Two senior representatives from the Government of Canada are also members. The Secretary of Energy has designated the Under Secretary as panel chairman. Terms are for 2 years, and members may be reappointed to additional 2-year terms. The 39-member panel is expected to operate for 5 years.

ICTAP held its first meeting on September 30, 1987, and its first report was issued in December 1987, recommending numerous factors that should be considered in the ICCT solicitation.[15]

During 1988 ICTAP met on February 25 and July 13 and is scheduled to meet on November 30 to consider other issues of significance to the demonstration program.

TASK FORCE ON REGULATORY RELIEF

Recognizing that the path to the marketplace will be dictated, in large part, by the regulatory climate under which clean coal concepts must compete, the President commissioned the Task Force on Regulatory Relief, chaired by the Vice President, to examine incentives and disincentives to the demonstration and deployment of new control technologies. On January 23, 1988, the President's acceptance of three general recommendations made by the Task Force was announced. These recommendations were for actions that should be taken by DOE, the Federal Energy Regulatory Commission, and the Environmental Protection Agency.

The Task Force recommended that DOE, in its ICCT solicitation, should consider giving preference in the award of federal funds for demonstrations, to projects located in states that offer certain regulatory incentives to encourage such technologies. DOE incorporated this recommendation into the project selection considerations in the PON.

PUBLIC MEETINGS

Four public meetings were convened by DOE during August and September 1987 to obtain views, comments, and recommendations on the forthcoming ICCT solicitation. The meetings took place in Albuquerque, New Mexico, on August 13; St. Louis, Missouri, on September 3; Pittsburgh, Pennsylvania, on September 10; and Washington, D.C., on September 22, 1987. Each meeting included a plenary session during which DOE officials made introductory remarks and presented program overviews. Attendees then broke into small discussion groups which ran concurrently to facilitate dicussions and make efficient use of the time available. Finally attendees reconvened in a closing plenary session. Highlights and recommendations from the small group discussions were then reviewed and summarized. Opening and closing plenary sessions were transcribed. DOE published

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[15] *Report to the Secretary of Energy Concerning Factors to be Considered in the First Innovative Clean Coal Technologies Program Solicitation*, Innovative Control Technology Advisory Panel, December 1987.

proceedings in November 1987.[16] Full consideration was given by DOE to the recommendations and comments of the public meetings in preparing the ICCT PON.

ICCT PROGRAM GUIDELINES

The guidelines developed for the ICCT solicitation reflect congressional guidance and the extensive public review and comment sought by DOE during the planning stages. These guidelines, as listed in the ICCT PON, are as follows:

1. The projects in this program will be industry projects assisted by the Government. The Congress has stipulated that Government funding shall not exeed 50% of total project costs....

2. Candidate technologies must be applicable to existing coal-burning facilities. However, the demonstration projects can be at new ("grassroots") facilities, as long as the technology is applicable to existing coal-burning facilities. Demonstration projects also may be conducted at existing oil- and gas-fired facilities, as long as coal is used and the technology is applicable to existing coal-fired facilities.

   The technology must be either capable of being retrofitted to existing facilities or capable of repowering existing facilities. For purposes of this PON, retrofit technologies are those technologies used to modify existing facilities to reduce SO_2 and/or NO_x emissions, which are acid rain precursors. Repowering technologies replace a significant portion of the original facility and, in addition to achieving significant emissions reductions, often increase capacity, extend the life of the plant, and improve the efficiency of the system.

   Retrofit technologies must have the potential to reduce significantly emissions of SO_2 and NO_x and minimize losses in efficiency....

   Repowering technologies must have the potential to reduce significantly emissions of SO_2 and/or NO_x, improve efficiency, and expand the capacity for energy production....

3. The PON is open to all market applications of innovative clean coal technologies that can lead to reduced emissions of SO_2 and/or NO_x from existing coal-burning facilities. This includes applications for utilities, industry, commercial and residential markets, and transportation.

4. In this PON, the terms "coal-burning" and "coal-fired" include coal utilization in existing facilities where coal is presently being used.

5. The evaluation criteria are tailored to be consistent with Congressional guidance and, as fully as practicable, with the recommendations of the Special Envoys on Acid Rain. Additionally, full consideration has been given to the recommendations and advice of the Innovative Control

[16] *Summary Proceedings: Public Meetings for Views and Comments on the Conduct of the Innovative Clean Coal Technology Solicitation*, Report No. DOE/FE-0094, U.S. Department of Energy, November 1987.

> Technology Advisory Panel, the Vice President's Task Force on Regulatory Relief, and the ICCT public meetings that were convened in August and September, 1987.[17]

The next chapter describes the issuance of the ICCT PON and summarizes the evaluation and selection of ICCT projects for award.

[17] Excerpted from the ICCT PON, pages 5-6.

III. ICCT PON and Project Selection

On December 22, 1987, with the enactment of Public Law No. 100-202,[18] Congress provided a total of $575 million for the ICCT program, as follows: appropriations of $50 million in fiscal year (FY) 1988 and $190 million in FY 1989, and advanced appropriations of $135 million in FY 1990 and $200 million in FY 1991. Of these monies, $6.782 million will be set aside for the Small Business and Innovative Research Program (SBIR) and are unavailable to the ICCT Program. Also, it is estimated that $32.512 million will be set aside for costs incurred by DOE in implementating the ICCT Program. The remaining $535.706 million are available for award under this PON. The budget is shown in Exhibit 2. No provision was made to hold funds in reserve to cover the cost of possible overruns.

Congress further required that DOE issue a "general request for proposals" for the ICCT Demonstration Program within 60 days of the date of enactment (by February 22, 1988) and provided 90 days from issuance of that request for the proposals to be submitted (by May 23, 1988). The selection of projects for negotiation was to be made within 160 days (by October 31, 1988). On September 28, 1988, the selection of 16 projects was announced. Immediately following selection, DOE and the proposers began to establish mutually agreed upon milestones for negotiation of cooperative agreements.

A chronology of the major events related to the ICCT solicitation is listed in Exhibit 3.

Exhibit 2

BUDGET FOR THE ICCT DEMONSTRATION PROGRAM

	(Thousands of Dollars)				
	FY 1988	FY 1989	FY 1990	FY 1991	Total
Available for ICCT Projects	$31,094	$173,816	$133,306	$197,490	$535,706
Program Direction	18,512	14,000	0	0	32,512
SBIR Program	394	2,184	1,694	2,510	6,782
Total	$50,000	$190,000	$135,000	$200,000	$575,000

[18] The fiscal year allocations of funds provided in Pub. L. No. 100-202, An Act Making Appropriations for the Department of the Interior and Related Agencies for the Fiscal Year Ending September 30, 1988, and for Other Purposes, signed into law on December 22, 1987, were amended by Pub. L. No. 100-446.

Exhibit 3

CHRONOLOGY OF MAJOR EVENTS RELATED TO THE ICCT PON

Major Event	Date
Designated Source Selection Official	Dec. 7, 1987
Established Source Evaluation Board	Dec. 8, 1987
Appropriations bill (Pub. L. No. 100-202) signed by the President	**Dec. 22, 1987**
Federal Register notice published	Jan. 25, 1988
Commerce Business Daily notice published	Jan. 25, 1988
Draft PON issued for comment	**Jan. 28, 1988**
Due date for comments on the draft PON	Feb. 5, 1988
Final PON issued*	**Feb. 22, 1988**
Receipt of questions for the preproposal conference	Mar. 8, 1988
Preproposal Conference held	Mar. 15, 1988
Questions and answers (Q's and A's) issued	Apr. 20, 1988
Amendment 1 issued	Apr. 20, 1988
Additional Q's and A's issued	Apr. 29, 1988
Amendment 2 issued	Apr. 29, 1988
Last Q's and A's issued	May 13, 1988
Closing date for receipt of proposals**	**May 23, 1988**
News Release and Public Abstracts issued	May 25, 1988
Letters sent to proposers who failed qualification review	June 29, 1988
Letters sent to proposers who failed preliminary evaluation	July 8, 1988
ICCT Selection Statement signed by Source Selection Official***	**Sept. 27, 1988**
Selections announced to the public	Sept. 28, 1988

* In accordance with Public Law No. 100-202, which provided that the PON be issued "no later than sixty days following enactment."

** In accordance with Public Law No. 100-202, which provided that proposals are due "no later than ninety days after issuance of the [PON]."

*** In accordance with Public Law No. 100-202, which provided that selection be made "no later than one hundred and sixty days after receipt of proposals," i.e., by October 31, 1988.

ISSUANCE OF THE ICCT PON

A draft PON was issued on January 28, 1988. The announcement that this draft was available for public comment was published in the *Federal Register* and the *Commerce Business Daily* on January 25, 1988. Public comments on the draft PON were received from 47 entities.

In response to the public comments received regarding the draft PON, the recommendations provided by the Innovative Control Technology Advisory Panel, and also as a result of the continuing process of PON review undertaken by the Source Evaluation Board, the final PON was modified to reflect a number of the ideas expressed in these comments. The final PON was issued on February 22, 1988.

Two amendments to the PON were issued. The first amendment, issued on April 20, 1988, revised sections of the PON dealing with, among other things, the recovery of the federal government's investment, the information requested in Appendix I, "The DOE Cost and Environmental Performance Methodology," of the PON, and the "Other Considerations" for project selection. The second amendment, issued on April 29, 1988, revised Exhibit F of Appendix K, "Cost Proposal Format (SF 1411) and Exhibits," to clarify that calendar year 1986 was the relevant time period for establishing the cost-sharing status of fully depreciated equipment or facilities.

Approximately 1500 copies of the PON were distributed. The Source List was developed from the roster of over 800 companies or individuals that had expressed an interest in the first clean coal technology solicitation. Approximately 400 names were added from the list of attendees at the four public meetings held throughout the country in the summer of 1987 and as a result of specific requests to be added to the mailing list. Finally, the Source List was augmented by requests received in response to the January 25, 1988, *Federal Register* and *Commerce Business Daily* notices of availability of the draft PON.

To enable prospective offerors to gain a better understanding of the objectives of this PON and to receive answers to written questions submitted regarding the PON, a Preproposal Conference was held on March 15, 1988.[19] Attendees also were afforded an opportunity to submit questions at the meeting. DOE estimates that approximately 250 persons attended the conference. On April 20, 1988, a comprehensive compilation of questions and answers (Q's and A's) addressed at the conference and most of the questions deferred for subsequent response were issued to all recipients of the PON and to all conference attendees. On April 29, 1988, and May 13, 1988, supplemental packages of Q's and A's were issued to address the inquiries received after the Preproposal Conference as well as a few questions from the Preproposal Conference that had been deferred for subsequent response.

[19] The March 15, 1988, Preproposal Conference was held at the U.S. Department of Commerce Auditorium, 14th & Constitution Avenues, N.W., Washington, DC 20004.

THE EVALUATION PROCESS

In announcing the selection of proposals for awards, the Source Selection Official, in his Selection Statement, provided an overview of the process used to evaluate the proposals received. Evaluations were performed by the Source Evaluation Board (referred to as the Board). The following description of the evaluation process is excerpted from the Selection Statement.[20]

1. **Proposals Received**

   On or before May 23, 1988, the closing date for submission of proposals, 54 proposals were received....

2. **Other Proposal**

   An additional proposal (from Carbonic International, Inc.) was received by another element of DOE, the Office of Energy Research (ER), prior to the May 23, 1988 deadline, but was forwarded to the Office of Procurement Operations after the deadline for receipt of proposals. In light of the date of receipt of this proposal by ER, it was determined that this proposal should be treated as "timely." Accordingly, this proposal was added to the list of proposals evaluated by the Board.

3. **Public Abstracts**

   In order to enable DOE to provide some information to the public regarding the number and nature of proposals received in response to the PON, the PON required that each offeror provide a public abstract of not more than 500 words, which described the proposed project, the specific innovative clean coal technology proposed, the project title, the submitter names(s), the mailing address of the primary submitter, the composition of the proposed project team, the methodology or approach to the project, and the anticipated timeframe of the demonstration effort. The offerors were further advised that this abstract might be released to the public, in whole or in part, at any time, and, therefore, should not contain proprietary data or confidential business information. On May 25, 1988, DOE issued a News Release that, among other things, announced that a compilation of public abstracts for candidate innovative clean coal technology projects was available for public inspection.[21] [Appendix B contains summary descriptions of the 55 proposed projects.]

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[20] *Selection of Proposals for the Demonstration of Clean Coal Technologies Program Opportunity Notice DE-PS01-88FE61530*, signed September 27, 1988, by the Source Selection Official, Donald L. Bauer, Principal Deputy Assistant Secretary for Fossil Energy, U.S. Department of Energy. Energy Secretary Herrington announced the awards on September 28, 1988.

[21] DOE News Release, "Clean Coal Competition Draws 54 Proposals for Innovative Pollution, Power Generating Technologies," May 25, 1988. (Footnote added.)

4. Qualification Review

The PON established six Qualification Criteria and provided that failure to meet one or more of these criteria would result in rejection of the proposal. These criteria addressed the location of the proposed project or facility, the use of coals from United States mines, the certifications required with respect to cost-sharing and repayment of the Government's investment, site availability, and the sufficiency of the teaming arrangement proposed. Six proposals failed to satisfy one or more qualification criteria, and, therefore, did not proceed to Preliminary Evaluation. These offerors were so advised by letters dated June 29, 1988.

5. Preliminary Evaluation

The PON established three Preliminary Evaluation requirements, and provided that failure to meet one or more of these requirements would result in rejection of the proposal. These requirements provided that the proposal must be consistent with the objectives of the PON, was required to contain sufficient technical, cost, and other information to enable Comprehensive Evaluation, and was to be signed by a responsible official of the proposing organization authorized to contractually bind the organization.

One proposal failed to satisfy one or more of these requirements, and, therefore, did not proceed to Comprehensive Evaluation. This offeror was so advised by letter dated July 8, 1988.

6. Comprehensive Evaluation

Proposal evaluation was conducted to determine the merits of each offeror's proposal in accordance with weighted evaluation criteria. The Technical Proposal evaluation resulted in a numerical score for each of the evaluation criteria.

The Business and Management Proposal was evaluated to determine the business and management performance potential of the offeror, and was used as an aid in determining the offeror's understanding of the technical requirements of this PON. The Business and Management Proposal was adjectivally rated, not point-scored.

The Cost Proposal was reviewed and evaluated to assess the validity of the proposer's approach to completing the project in accordance with the proposed Statement of Work and the requirements of this PON. No point score or adjectival rating was applied.

To determine the overall merit of each proposal, the Technical, Business and Management and Cost sections were considered in accordance with the relative weights established in the PON. In particular, the PON provided that the Technical Proposal is of somewhat greater importance than the Business and Management Proposal and that the Cost Proposal is minimal. However, everything else being equal, the Cost Proposal is very important.

6.1 Technical Evaluation Criteria

The Technical Evaluation Criteria were divided into two major categories. The first, "Commercialization Factors," addressed the projected commercialization of the proposed technology. The criteria in this category provided for consideration of (1) the potential of the technology to reduce total national emissions of SO_2 and/or NO_x emissions and reduce transboundary and interstate air pollution, with minimal adverse environmental, health, safety, and socio-economic impacts, (2) the potential of the proposed technology to improve the cost-effectiveness of controlling emissions of SO_2 and NO_x when compared to commercially available technology options.

The second major category, "Demonstration Project Factors," recognized that the proposed demonstration project represented the critical step between the "pre-demonstration" scale of operation and commercial readiness, and dealt with the proposed project itself. Criteria in this category provided for consideration of technical readiness for scale-up; the adequacy and appropriateness of the demonstration project; the environmental, health, safety, socio-economic and other site-related aspects; the reasonableness and adequacy of the technical approach and quality and completeness of the Statement of Work and management plan for the demonstration.

7. Business and Management Evaluation Criteria

The Business and Management Evaluation Criteria provided for consideration of (1) the adequacy and completeness of the plan to finance the project, including the financial condition and capability of the proposed funding sources; (2) the commitment of the project team's management to the project and its subsequent commercialization; (3) the adequacy of the commercialization plan; and (4) the organizational credentials, availability, and quality of project resources.

8. Program Policy Factors

The PON also provided three program policy factors for consideration by the Source Selection Official in selecting proposals, which, when taken together, would best achieve the program goals and objectives. These program policy factors are:

(1) The desirability of selecting projects for retrofitting and/or repowering existing coal-fired facilities that collectively represent a diversity of methods, technical approaches, and applications (including both industrial and utility);

(2) The desirability of selecting projects that collectively produce some near-term reduction of transboundary transport of emitted SO_2 and NO_x; and

(3) The desirability of selecting projects that collectively represent an economic approach applicable to a combination of existing facilities that significantly contribute to transboundary and interstate transport of SO_2 and NO_x in terms of facility types and sizes, and coal types.

9. Other Considerations

The PON also provided that, in the selection process, DOE would consider giving preference to projects located in states where the rate-making bodies of those states treat innovative clean coal technologies the same as pollution control projects or technologies. The inclusion of this project selection consideration was intended to encourage states to utilize their authorities to promote the adoption of innovative clean coal technology projects as a means of improving the management of air quality within their areas and across broader geographical areas.

The PON provided that this consideration would be used as a tie breaker if, after application of the evaluation criteria and the program policy factors, two projects received identical evaluation scores and remained essentially equal in value. This consideration would not be applied if, in doing so, the regional geographic distribution of the projects selected would be altered significantly.

10. Discussions with Offerors

In light of the number of proposals received and the time constraints created by the statutory deadlines established for this program, there was no opportunity to engage in written or oral discussions prior to selection.

11. National Environmental Policy Act (NEPA) Strategy

An overall strategy for compliance with NEPA was developed for the ICCT Program, consistent with the Council on Environmental Quality NEPA regulations and the DOE guidelines for compliance with NEPA. This strategy includes both programmatic and project-specific environmental impact considerations, during and subsequent to the selection process.

In light of the tight schedule imposed by Pub. L. No. 100-202 and the confidentiality requirements of the competitive PON process, DOE established alternative procedures to ensure that environmental factors were fully evaluated and integrated into the decision making process to satisfy its NEPA responsibilities. Offerors were required to submit both programmatic and project-specific environmental data and analysis as a discrete part of their proposal.

This NEPA strategy has three major elements. The first involves preparation of a comparative programmatic environmental impact analysis, based on information provided by the offerors and supplemented by DOE, as necessary. The environmental analysis ensures that relevant environmental consequences of the ICCT Program and reasonable programmatic alternatives are evaluated in the selection process. The second element involves preparation of a pre-selection project specific environmental review. The third element provides for preparation by DOE of site-specific NEPA documents for each project selected for financial assistance under the PON.

No funds from the ICCT Program will be provided for detailed design, construction, operation and/or dismantlement until the third element of the NEPA process has been successfully completed. In addition, each cooperative agreement will require an environmental monitoring plan to ensure that significant technology, project and site-specific environmental data are collected and disseminated. [Chapter V contains a more detailed discussion of environmental considerations.]

SELECTION DECISION

After considering the evaluation criteria, the program policy factors, and the NEPA strategy as stated in the PON, the Source Selection Official selected 16 proposals as best furthering the goals and objectives of this PON. These projects are listed in Exhibit 4.

Brief summaries of each project selected follow. Summaries of all proposals received are contained in Appendix B and are organized by the identification number assigned at random to each proposal received. (Note: Proposal numbers reflect **no** judgment on the relative merits of the proposals.) These identifying proposal numbers are shown below in brackets as an aid in referring to the summaries in the appendix.

1. **American Electric Power Service Corporation [Proposal No. 18]**

   The proposer intends to repower two commercially operating 150 MWe pulverized coal fired electric generating units of early 1950's vintage by replacing the two boilers with a single pressurized fluidized bed (PFB) combustor/gas turbine module capable of generating 330 MWe. The net thermal efficiency of the repowered plant will be about 38% (with SO_2 and NO_x control); this compares with the present efficiency of 36.5% (without SO_2 and NO_x control). Specific performance objectives when burning high-sulfur (4%) coal are expected to result in greater than 90% sulfur retention and less than 0.3 lb. NO_x emissions per million Btu.

   The project is based on more than 10 years of development work by the proposer on PFB technology and will build upon the experience gained from the 70 MWe Tidd PFB Demonstration Plant currently under construction under the first Clean Coal Technology solicitation. The units to be repowered are located at the Philip Sporn Plant in Mason County, West Virginia.

Exhibit 4

INNOVATIVE CLEAN COAL TECHNOLOGY PROJECTS SELECTED BY THE DEPARTMENT OF ENERGY

No.*	Proposer	Technical Approach	Project Location
1	Southern Company Services, Inc. Birmingham, AL	Advanced wet limestone; unique absorber design combining desulfurization, forced oxidation and gypsum crystallization	Newnan (near Atlanta), Coweta and Carroll Cos., GA
2	Southern Company Services, Inc. Birmingham, AL	Advanced overfire air; second generation low-NO_x burner	Rome, Floyd Co., GA
3	Southern Company Services, Inc. Birmingham, AL	Selective catalytic reduction	Pensacola, Escambia Co., FL
4	Southern Company Services, Inc. Birmingham, AL	Advanced overfire air; advanced tangentially fired system	Lynn Haven (near Panama City), Bay Co., FL
6	Combustion Engineering, Inc. Windsor, CT	Optimized application of in-duct injection; in-duct spray drying; and convective pass injection	Yorktown, York Co., VA
7	Combustion Engineering, Inc. Windsor, CT	Air blown dry feed entrained flow gasifier with an advanced coal feeder and limestone injection, moving bed hot gas cleanup integrated with gas and steam turbines	Springfield, Sangamon Co., IL
9	Combustion Engineering, Inc. Windsor, CT Snamprogetti U.S.A., Inc. New York, NY	Catalytic reduction of SO_2 and NO_x; no solid waste produced	Niles, Trumbull Co., OH
11	The Babcock & Wilcox Company Alliance, OH	Sorbent injection; selective catalytic reduction; high-temperature baghouse	Dilles Bottom, Belmont Co., OH

* Numbers were assigned to proposals at random and reflect no judgment on the relative merits of the proposals.

Exhibit 4 (Continued)

INNOVATIVE CLEAN COAL TECHNOLOGY PROJECTS SELECTED BY THE DEPARTMENT OF ENERGY

No.*	Proposer	Technical Approach	Project Location
16	Southwestern Public Service Company Amarillo, TX	Circulating fluidized-bed	Near Amarillo, Potter Co., TX
17	Passamaquoddy Tribe Thomaston, ME	Recovery scrubber for cement kiln; generates no solid waste and uses waste from cement kiln	Thomaston, Knox Co., ME
18	American Electric Power Service Corporation Columbus, OH	Bubbling pressurized fluidized-bed; combined-cycle	New Haven, Mason Co., WV
19	Bethlehem Steel Corporation Bethlehem, PA	Gas stream cleanup of coke oven gas in a steel plant; generates no solid waste	Sparrows Point (near Fort Howard), Baltimore Co., MD
21	The Babcock & Wilcox Company Alliance, OH	Reburning using coal; NO_x control	Cassville, Grant Co., WI
25	Pure Air Allentown, PA	Advanced wet limestone; single absorber module with no spare; high velocity concurrent absorber; profitable "sulfur disposal service"	Gary, Lake Co., IN
41	TransAlta Resources Investment Corporation Calgary, Alberta, Canada	Advanced slagging combustor; Low NO_x/SO_x burner; coal pulverizer system	Marion, Williamson Co., IL
46	Otisca Industries, Ltd. Syracuse, NY	Selective agglomeration/coal-water slurry	Syracuse, Onondaga Co. Jamesville, Onondaga Co. Oneida, Oneida Co. All in NY

* Numbers were assigned to proposals at random and reflect no judgment on the relative merits of the proposals.

2. **Bethlehem Steel Corporation [Proposal No. 19]**

This proposal involves retrofitting the existing coke gas cleaning plant (coal chemical plant) at the Bethlehem Steel Sparrows Point (Maryland) steel plant which consists of two coke batteries. Currently, the coke oven gas (COG) from the smaller of the two batteries is recycled directly to the coke ovens without chemical recovery or cleanup. The COG from the larger of the two batteries undergoes both chemical recovery and cleanup prior to its use as fuel gas in various plant operations.

Under the proposed project, the COG would be cooled using a recirculating liquor with a (closed) indirect cooling tower thus eliminating the benzene and other emissions associated with the atmospheric final gas cooling tower now in use. Ammonia and H_2S would be removed by absorption into an ammonia liquid solution with subsequent steam stripping of the combined H_2S and ammonia vapors. This combined stream is then passed to a system where the ammonia is catalytically destroyed (i.e., converted to H_2 and N_2) and a portion of the H_2S is oxidized to SO_2 for input to the Claus plant as a combined H_2S/SO_2 stream. The COG that streams from both coke batteries would be processed with this system.

3. **Combustion Engineering, Inc. (Dry Sorbent Injection) [Proposal No. 6]**

This project is a demonstration of three dry sorbent injection technologies: In-Duct Injection, In-Duct Spray Drying, and Convective Pass Injection for flue gas desulfurization. The technologies involve injection of a calcium-containing sorbent either into the convective pass of the furnace or into the duct between the air preheater and the particulate control device. The sulfur dioxide in the flue gas reacts with calcium to form dry chemical compounds, calcium sulfite and calcium sulfate, which are removed in the particulate control device along with fly ash.

This 180 MWe demonstration involves the retrofit of Virginia Electric and Power Company's Yorktown Plant Unit 2 in York County, Virginia. The objectives of this program are (1) to demonstrate reduction in sulfur oxide emission by fifty percent or greater using these technologies, and (2) to provide technical, economic, environmental and operating data to support commercialization of these technologies by the electric power generation industry.

4. **Combustion Engineering, Inc. (Repowering) [Proposal No. 7]**

This project will demonstrate Combustion Engineering's pressurized, airblown, entrained-flow coal gasification repowering technology on a commercial scale. The syngas will be cleaned of sulfur and particulates and then combusted in a gas turbine (40 MWe) from which heat will be recovered in a heat recovery steam generator (HRSG). Steam from the gasification process and the HRSG will be used to power an existing steam turbine (25 MWe).

The proposed project is selected for demonstration at the Lakeside Generating Station of City Water, Light and Power, Springfield, Illinois. The selected site with associated characteristics and costs includes repowering an existing steam turbine to produce 65 MWe of electricity via the combined cycle mode. The process will remove about 12 tons per day of sulfur from a daily consumption of 480 tons of high sulfur (2.5%) Illinois No. 5 coal, a reduction efficiency of over 99%. NO_x is expected to be reduced by over 80%.

5. **Combustion Engineering, Inc., and Snamprogetti U.S.A., Inc. [Proposal No. 9]**

The proposed project is for the purpose of demonstrating the WSA-SNOX technology for catalytically removing both SO_2 and NO_x from flue gas and producing a saleable byproduct, concentrated sulfuric acid. No sorbents are used; consequently waste byproducts which normally result from their use are not formed. Two catalytic reactors are used to first remove NO_x by converting it to N_2 in an SCR reactor and then to oxidize the SO_2 to SO_3. The SO_3 is subsequently hydrated and then condensed as H_2SO_4 in the WSA tower.

The 35 MWe demonstration will be conducted by retrofitting an 100 MWe existing power plant, Ohio Edison's Niles Station Boiler No. 2 in Trumbull County, Ohio. The objective of this project is to demonstrate the WSA-SNOX technology on an electric power plant firing high sulfur Ohio coal. A reduction efficiency of 90% or more for both SO_2 and NO_x is expected. The demonstration will feature full-scale components and modules.

6. **Otisca Industries, Ltd. [Proposal No. 46]**

The purpose of the proposed project is to demonstrate the manufacture, storage, handling, and utilization of an ultra clean coal water slurry, known as [OTISCA FUEL]. The core of the manufacturing process for [OTISCA FUEL] is the Otisca-T Process, which consists of reducing the raw particle size to effect the releases of mineral matter from the coal, and recovering the ultra clean coal via a selective agglomeration process that employs pentane as the agglomerating agent. The pentane is removed from the recovered ultra clean product coal and reused. Less than 0.25 weight percent pentane remains with product coal. The mineral matter and pyrite remain in the aqueous phase and are removed from processor water by settling. This process is claimed to remove virtually all the pyritic sulfur and a significant quantity of the mineral matter from virtually any coal, while recovering over 95% of the input coal Btu's in the product coal.

The [OTISCA FUEL] will be retrofitted to industrial boilers that are used for the production of steam. The proposed program will support the conversion of up to seven industrial boilers in the central New York state area (Syracuse, Jamesville and Oneida) from their existing configuration, i.e., the burning of oil, gas, or high sulfur coal, to one that allows the combustion of [OTISCA FUEL].

7. **Passamaquoddy Tribe [Proposal** No. 17]

The Passamaquoddy Tribe intends to demonstrate a scrubbing system for removing SO_2 emissions from existing coal-burning cement kilns. The project features the Tribe's "Recovery Scrubber", which can reduce SO_2 emissions by over 90%, uses kiln waste dust as the scrubbing reagent, produces a recycle stream for feeding to the kiln and two potentially saleable by-products (potassium-based fertilizer and distilled water), and generates no new wastes.

The demonstration involves retrofit of the Tribe's cement plant, Dragon Products Company, which is located in Thomaston, Maine. The demonstration will treat the entire gas stream from the cement kiln, which has a capacity of 470,000 tons/year of cement clinker. By-product recovery will be demonstrated through the use of a heat exchanger/evaporator.

8. **Pure Air [Proposal No.** 25]

This retrofit project is for a commercial scale advanced limestone scrubber flue gas desulfurization (FGD) system. A single, 529 MWe absorber module will treat the flue gas from four existing boilers.

The system design will use a high velocity, cocurrent flow absorber with direct injection of pulverized limestone. The system design includes a new, and innovative, single-loop process which produces commercial gypsum, using in-situ forced oxidation accomplished by a rotary air sparger. A novel waste water evaporation system will be evaluated that potentially eliminates water disposal/treatment problems associated with the use of high chloride content coals and essentially provides no water discharge. A cyclic reheater will be used to reduce the operating costs normally associated with stream reheat. The overall goal of the project is to demonstrate that the innovative features of the proposed approach combined with by-product gypsum sales will result in a system capable of 90% or higher SO_2 capture at a cost that is 50% lower than that which can be achieved by currently available FGD systems.

The proposed demonstration site is the Northern Indiana Public Service Company's Dean H. Mitchell Station located in Gary, Indiana.

9. **Southern Company Services, Inc.** (Chiyoda-121) **[Proposal No. 1]**

The proposed project is for the demonstration of the Chiyoda Thoroughbred-121 flue gas desulfurization process. This process uses a unique absorber design known as the jet bubbling reactor which combines limestone FGD reactions, forced oxidation and gypsum crystallization in one process vessel. As a result, the process is mechanically and chemically simpler than conventional FGD processes and can be expected to exhibit lower cost characteristics. As part of the demonstration, innovations to this process will be evaluated to determine whether costs can be reduced further, including the use of [a] fiberglass reinforced plastic absorber, elimination of flue gas [reheat] and a spare absorber module, and gypsum stacking to reduce waste management costs. The ability of this technology to remove particulates will also be evaluated.

A 2.9% sulfur coal will be used for the demonstration which will be conducted by retrofitting Georgia Power Company's 100 MWe Yates ... Plant Unit 1, [in Newnan] near Atlanta, Georgia. Project objectives include the demonstration of 90% SO_2 control at high reliability with and without simultaneous particulate control.

10. **Southern Company Services, Inc. (Selective Catalytic Reduction) [Proposal No. 3]**

This retrofit project is for the purpose of demonstrating that a combination of combustion modification technology and Selective Catalytic Reduction (SCR) provides the most cost effective means of reducing nitrogen oxide emissions from power plants. The demonstration will focus on the application of SCR to high sulfur coals.

The demonstration plant will be located between Units 5 (75 MWe) and 6 (320 MWe) of Gulf Power Company's Plant Crist near Pensacola, Florida. This location allows access to flue gas from approximately 3% sulfur coal under a variety of different NO_x and particulate levels.

Once SCR has been demonstrated to operate economically on high-sulfur American coals, it will represent a technology which has the capability to obtain 90% reduction of NO_x emissions for utility and industrial boilers. The technology can potentially be applied to all types of boilers, including cyclone-fired boilers which cannot be easily retrofitted with other developing NO_x control technologies.

11. **Southern Company Services, Inc. (Tangential-fired NO_x) [Proposal No. 4]**

The project proposed by Southern Company Services will demonstrate three advanced NO_x control technologies for retrofit applications to tangential-fired, pulverized-coal boilers: (1) advanced over-fire air which consists of deep stage high rate air injection, (2) low NO_x concentric fired systems, and (3) advanced tangential fired systems. The advanced NO_x control technologies will be sequentially applied to a single tangential-fired boiler at Unit 2 of Gulf Power Company's Plant Smith in Lynn Haven, Florida. The proposed 180 MWe demonstration boiler is representative of a large class of tangential boilers.

The performance and NO_x reduction capabilities of each advanced NO_x reduction technology will be evaluated separately and then in combined operation in a logical sequence on a single reference demonstration boiler. The combination is expected to reduce NO_x by up to 60%. Each technology will be tested for at least three months under typical dynamic boiler operating conditions. This will ensure an accurate, comparative measure of the long-term NO_x reduction capabilities of each technology under typical operating conditions.

12. Southern Company Services, Inc. (Wall-fired NO_x) [Proposal No. 2]

Southern Company Services, Inc. intends to demonstrate three advanced NO_x control technologies for retrofit applications to wall-fired, pulverized-coal boilers. The three NO_x control technologies are Advanced Overfire Air (AOFA) which consists of deep stage high rate air injection, second generation low NO_x burner (LNB), and LNB with AOFA. The advanced NO_x control technologies will be sequentially applied to a single furnace, sub-critical, wall-fired boiler at the Georgia Power Company's Hammond Plant Unit 4 at Rome, Georgia. The proposed 500 MWe demonstration boiler is representative of a large class of wall-fired boilers.

The performance and NO_x reduction capabilities of each advanced NO_x control technology will be evaluated separately first and then in combined operation on the same demonstration boiler. The combination is expected to reduce NO_x emission[s] by up to 60%. Each technology will be tested for at least 3 months under typical dynamic boiler operating conditions. This will ensure an accurate, comparative measure of the NO_x reduction capabilities and performance characteristics of each of these technologies.

13. Southwestern Public Service Company [Proposal No. 16]

Southwestern Public Service Company (SPS) is proposing to repower an existing 256 MWe steam turbine generator at the Nichols Station Power Plant, located near Amarillo, Texas, using a circulating fluidized bed (CFB) boiler. This repowering project is intended to demonstrate the use of a scaled-up CFB boiler in order to promote commercialization of larger size CFB boilers than are presently available. The boiler will generate 1,800,000 lbs/hr of steam at 2005 psi and 1005° F. The preheater will be of the heat pipe type--a relatively new innovation in utility boiler applications. The CFB is scheduled to burn Wyoming and New Mexico subbituminous coal.

The largest CFB boiler now under construction is the Combustion Engineering boiler for [a] 150 MWe lignite-fueled unit at Texas-New Mexico Power's (TNP) plant. SPS's proposed demonstration is approximately 1.6 times larger than the TNP boiler. There will be a 2 year test program after which the facility will continue to operate commercially. For the repowered facility, SO_2 and NO_x will be controlled by 70% and over 80%, respectively.

14. The Babcock & Wilcox Company (Cyclone Reburning) [Proposal No. 21]

The objective of this project is to demonstrate that coal can be used as a reburning fuel for reducing nitrogen oxides on a coal-fired cyclone boiler. Reburning technology is the only in-furnace NO_x control technology that has been shown to be technically feasible for cyclone boilers.

A coal reburning retrofit will be designed, fabricated and installed in Wisconsin Power & Light Company's Nelson Dewey Plant Unit #2 which is located along the Mississippi River in Cassville, Wisconsin. Pilot scale testing and mathematical modeling will be utilized in the retrofit design. A successful demonstration of the coal reburning technology could result in achieving a 50% NO_x reduction with no resultant decrease in boiler efficiency. This technology is expected to be applicable to all cyclone boilers larger than about 80 MWe.

15. **The Babcock & Wilcox Company (SOX-NOX-ROX Box) [Proposal No. 11]**

This project is a post-combustion flue gas cleanup demonstration of combined removal of SO_2, NO_x and particulates. Ammonia and a calcium-based sorbent are injected upstream of a high temperature baghouse. The sorbent reacts with SO_2 and is removed in the baghouse. In the presence of the selective catalytic reduction (SCR) catalyst, NO_x is reduced by NH_3 to nitrogen and water. Particulate removal is accomplished in the baghouse using high temperature bags. It is estimated that SO_2 removals of about 50% or more can be achieved with NO_x removals of 90% and particulate removals exceeding 99% in a single unit.

This SOX-NOX-ROX Box concept will be demonstrated by retrofitting a 5 MWe slipstream of flue gas at Ohio Edison's R.E. Burger Station in Belmont County, Ohio.

16. **TransAlta Resources Investment Corporation [Proposal No. 41]**

For this project, TransAlta proposes to retrofit and demonstrate a low NO_x/SO_x (LNS) Burner and a coal pulverizer system on the 33 MWe Unit/cyclone boiler at Southern Illinois Power Cooperative's Marion Plant in Marion, Illinois. Two LNS burners, each rated at 200 million Btu/hr, will be retrofitted to the existing Babcock & Wilcox cyclone boilers, and are expected to reduce both NO_x and SO_2 emissions by up to 90%.

The LNS Burner is a three-stage, entrained flow slagging combustion system. Sulfur is captured by injecting limestone at a calcium to sulfur ratio of 2 or less in ... [the] primary stage. In the second ... stage, gaseous nitrogenous compounds, including NO_x, are converted to molecular nitrogen. Finally, in the third stage excess air is added to complete combustion and to obtain full heat release. It is in the second (i.e., NO_x destruction) stage that combustion temperatures are sufficiently high to allow removal of molten slag which includes the captured sulfur in a glassy ash matrix. TransAlta's LNS Burner retrofit also includes a simple impact-type separation, in which a series of tubes extend vertically down through the gas stream to remove approximately 80% of the fly ash.

COLLECTIVE SO_2 AND NO_x REDUCTIONS

Based on information available in proposals, best estimates were made of potential SO_2 and NO_x reductions that might be achieved collectively by the selected projects. The collective SO_2 and NO_x reductions at the plant sites were estimated to be approximately 175,000 tons per year and 24,000 tons per year respectively. These are annualized reductions based on a 70-percent capacity factor.

IV. Descriptions of ICCT Proposals Received

Fifty-five proposals were received in response to the Innovative Clean Coal Technology Program Opportunity Notice (PON). Although the PON restricted projects to those technologies that, among other things, are capable of achieving significant reduction of SO_2 and NO_x emissions from existing coal-burning facilities, the proposals exhibit substantial diversity in terms of such dimensions as technologies embraced, project size and duration, geographic distribution, type of coal used, and environmental and commercialization characteristics. The following discussion provides an overview of the proposals received in response to the PON. This discussion provides only limited information on the characteristics of the proposals; the reader is referred to Appendix B for summary descriptions of each proposed project.

TECHNOLOGIES PROPOSED

The proposed projects generally can be assigned to one of the major advanced technology categories. These categories and the number of proposals received in each category are shown in Exhibit 5. The greatest number of proposals received in any category was 18 and involved flue gas cleanup. In addition, relatively large numbers of proposals were received for the fluidized-bed combustion category (13) and coal processing (7). Together, these three technology categories account for more than two-thirds of the 55 proposals received. Of the remaining 17, 15 proposals were distributed among the following technology categories: integrated gasification combined-cycle (6), advanced combustion (5), combined technologies (2), and industrial processes (2). The remaining two proposals are listed in the "Miscellaneous" category. One of these proposed a technology (i.e., a coal/heavy oil hydrogeneration plant) that did not fit into the identified major categories and the second involved CO_2 cleanup of the flue gas. It did not fit in with the other flue gas cleanup projects which deal primarily with SO_2 and NO_x removal.

Exhibit 6 identifies the proposer and technical approach associated with each proposal. Appendix B provides additional information. The proposal number listed on the exhibit is a cross-reference to aid in locating the appropriate project summary in the Appendix.

PROJECT SIZE AND DURATION

Project size and duration are dimensions on which the 55 proposals show considerable diversity. Exhibit 7 lists this information for projects grouped by technology category. The size of projects is indicated by the amount of coal processed, energy output capacity, and/or product yield, depending on the data provided by the proposer. The offerors have proposed projects that range from 0.65 ton per hour to 5,687 tons per hour of coal feed; 500 kWe to 750 MWe power output.

Project schedules also vary considerably, ranging from 12 months to 108 months depending upon the scope of the project. More specifically, 40 percent of the projects have schedules of 3 to 4 years, and 66 percent are scheduled to be completed in 5 years

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or less. With the exception of 3 projects, which did not provide a specific time frame, the remaining projects require 6 to 9 years to complete.

GEOGRAPHIC DISTRIBUTION

The geographic locations of the proposed projects are substantially concentrated in the higher sulfur coal producing and coal-using states of the North-East, North-Central, and Mid-Atlantic regions. More than half of the proposed project sites (i.e., 29 projects) are located in four states: Illinois (10), Ohio (9), Pennsylvania (5), and Florida (5). Another 11 proposed project sites are located west of the Mississippi River. Exhibit 8 lists the proposer's state as well as the county and state where the proposed project would be located.

SULFUR LEVELS OF COALS

The domestic coal resource base exhibits widely varying properties (e.g., sulfur, ash, and volatiles content; heat value; hardness) depending on mining location. Of particular concern at present is the ability of these technologies to be able to burn a range of coals with medium- to high-sulfur contents in an environmentally acceptable manner. Most of the projects proposed to demonstrate their ability to burn coals of high- to low-sulfur levels. However, several projects proposed to concentrate on burning medium- to high-sulfur coals; only a few proposed to demonstrate the use of only low-sulfur coals. Exhibit 9 lists the ranges of sulfur levels in coals proposed for utilization in future commercial applications.

ENVIRONMENTAL AND COMMERCIALIZATION CHARACTERISTICS

For each technology category addressed by ICCT, Exhibit 10 identifies several environmental and commercialization characteristics, including:

- **Date of Commercialization**--Most technologies are expected to be available starting in the mid-1990s.

- **U.S. Region of Applicability**--All technology categories are expected to apply nationwide, except for fuel upgrading which is targeted for western subbituminous coals.

- **Coal Type**--With two exceptions, the technology will be capable of using all ranks of coal; however, advanced combustors are targeted at subbituminous and bituminous coals and fuel upgrading at western subbituminous coals.

- **Emissions Reductions**--Integrated gasification combined-cycles, coal/oil/coprocessing, fluidized-bed combustion, flue gas cleanup with tailgas sulfur control, and some industrial processes achieve the greatest degree of SO_2 emissions reductions, i.e., more than 90 percent. Integrated gasification combined-cycles and coal/oil coprocessing are also expected to be the most effective technologies for reducing NO_x emissions, achieving 90-95 percent reductions.

Exhibit 5

DISTRIBUTION OF PROPOSALS BY TECHNOLOGY CATEGORY

Technology Category	Code	Number of Proposals
Advanced Combustion	ADC	5
Coal Processing		
Coal Preparation	CPR	3
Fuel Upgrading	FUP	4
Combined Technologies	CBT	2
Flue Gas Cleanup		
Combined SO_2/NO_x Control	FGC	5
NO_x Control	FGN	7
Sulfur Control–Injection	FSI	3
Sulfur Control–Tailgas	FST	3
Fluidized-Bed Combustion (FBC)		
Atmospheric FBC–Industrial	AFI	2
Atmospheric FBC–Utility	AFU	9
Pressurized FBC	PFB	2
Industrial Processes	IND	2
Integrated Gasification Combined-Cycle (IGCC)	IGC	6
Miscellaneous	MSC	2
Total		55

Exhibit 6

PROPOSED TECHNICAL APPROACHES BY TECHNOLOGY CATEGORY

Technology	No.*	Proposer	Technical Approaches
Advanced Combustion	23	Cogentrix/Coastal Joint Venture	Micropulverization of coal and limestone injection into low NO_x burners
	36	Coal Dynamics Corporation	Generate electricity from hot air extracted from coal mine fire; no solid waste generated
	41	TransAlta Resources Investment Corporation	Slagging combustor
	47	Energy Partners, Inc.	Micropulverization of coal and limestone injection into boiler
	50	En-R-Tech International, Inc.	En-R-Tech clean coal process for particulate control
Coal Processing--Coal Preparation	44	CYCLEAN, INC.	Microwave coal processing; pyrite agglomeration; air classifier/separator
	45	CLI Corporation	Fine coal cleaning in a dense media cyclone using micronized magnetite; chemical coal cleaning; coal/water slurry product
	46	Otisca Industries, Ltd.	Selective agglomeration/coal-water slurry
Coal Processing--Fuel Upgrading	13	Western Energy Company	Advanced dewatering process for low rank coals
	26	Char-Fuels Associates, Ltd.	Thermal volatilization to produce char-based slurry (char, hydrocarbon liquid, and water) and high value byproducts; no solid waste
	42	Minnesota Power	Coal beneficiation using hot water drying technology
	52	K-Fuel Partnership	High pressure pyrolysis tar recovery and coal pelletizing to upgrade high moisture, low rank feedstocks; no solid waste

* Proposal identification number. For further information, see Appendix B.

Exhibit 6 (Continued)

PROPOSED TECHNICAL APPROACHES BY TECHNOLOGY CATEGORY

Technology	No.	Proposer	Technical Approaches
Combined Technologies	40	Virginia Electric and Power Company	Coal cleaning plant; clean fuel burned in pulverized coal plant; middling fuel dried and burned in CFB; utility repowering
	43	Duquesne Light Company	Coal optimization process; advanced froth flotation; on-line control technology to combine cleaning and sorbent injection
Flue Gas Cleanup--Combined SO_2/NO_x Control	9	Combustion Engineering, Inc. & Snamprogetti U.S.A., Inc.	Catalytic reduction of SO_2 and NO_x; no solid waste produced
	11	The Babcock & Wilcox Company	Sorbent injection, selective catalytic reduction; baghouse
	29	Montana State University	SO_2 and NO_x removal from flue gas using petroleum pitch
	34	NOXSO Corporation	Alkali sorbent; fluidized-bed contractor; NH_3 injection; regenerable sorbent
	54	Helipump Corporation	Electrochemical reduction concept for SO_2 and NO_x control; no solid waste produced
Flue Gas Cleanup--NO_x Control	2	Southern Company Services, Inc.	Advanced overfire air; second generation low NO_x burner
	3	Southern Company Services, Inc.	Selective catalytic reduction
	4	Southern Company Services, Inc.	Advanced overfire air; advanced tangentially fired system
	5	Combustion Engineering, Inc.	Reburning using coal
	20	The Babcock & Wilcox Company	Advanced low NO_x cell burner
	21	The Babcock & Wilcox Company	Reburning using coal
	32	Ultrasystems Engineers & Constructors, Inc.	Selective catalytic reduction

Exhibit 6 (Continued)

PROPOSED TECHNICAL APPROACHES BY TECHNOLOGY CATEGORY

Technology	No.	Proposer	Technical Approaches
Flue Gas Cleanup--Sulfur Control (Injection)	6	Combustion Engineering, Inc.	Optimized application of in-duct injection; in-duct spray drying and convective pass injection
	22	The Babcock & Wilcox Company	Furnace limestone injection; dry scrubbing
	24	Bechtel National, Inc.	Confined zone dispersion of lime slurry spray in duct work
Flue Gas Cleanup--Sulfur Control (Tailgas)	1	Southern Company Services, Inc.	Advanced wet limestone; unique absorber design combining desulfurization, forced oxidation, and gypsum crystallization
	25	Pure Air	Advanced wet limestone; single absorber module with no spare; high velocity cocurrent absorber; profitable "sulfur disposal service"
	48	Northern States Power Company	Advanced wet limestone; unique bubbler combined with electrostatic enhancements; minerals processing plant; no solid waste generated
Fluidized Bed Combustion--Atmospheric (Industrial)	12	Pedco, Inc.	Rotary cascading bed (rotary kiln technology)
	27	Southern Illinois University at Carbondale	Circulating fluid bed with programmed fuel blender to utilize waste coal fuels

Exhibit 6 (Continued)

PROPOSED TECHNICAL APPROACHES BY TECHNOLOGY CATEGORY

Technology	No.	Proposer	Technical Approaches
Fluidized Bed Combustion--Atmospheric (Utility)	14	City of Independence, Missouri	Circulating fluid bed with external fluid bed heat exchanger for preheating air to a gas-fired turbine
	16	Southwestern Public Service Company	Circulating fluid bed
	28	Tennessee Valley Authority	Bubbling fluid bed
	30	Staley Continental, Inc.	Multi-solids (combined circulating and dense beds) fluid bed
	31	Tennessee Valley Authority	Hybrid (between bubbling and circulating fluid-bed
	38	Manitowoc Public Utilities	Circulating fluid bed
	39	Modular Power Plant Limited Partnership	Modularized circofluid bed with freeboard heat exchanger for steam production
	49	Lignite Research Council	Fluid bed cogeneration with gasification
	51	City of Tallahassee, Florida	Circulating fluid bed
Fluidized Bed Combustion--Pressurized	18	American Electric Power Service Corporation	Bubbling pressurized fluid bed
	37	Allison Gas Turbine Division, General Motors Corporation	Advanced PFBC; pressurized carbonizer with in-bed desulfurization; topping combustor; high temperature turbine
Industrial Processes	17	Passamaquoddy Tribe	Recovery scrubber for cement kiln; generates no solid waste and uses waste from cement kiln
	19	Bethlehem Steel Corporation	Gas stream cleanup of coke oven gas in a steel plant, generates no solid waste

Exhibit 6 (Continued)

PROPOSED TECHNICAL APPROACHES BY TECHNOLOGY CATEGORY

Technology	No.	Proposer	Technical Approaches
Integrated Gasification Combined Cycle	7	Combustion Engineering, Inc.	Air blown dry feed entrained flow gasifier with an advanced coal feeder and limestone injection, moving bed hot gas cleanup integrated with gas and steam turbines
	8	Florida Power & Light Company	Oxygen blown dry feed entrained flow gasifier with MDEA gas cleaning and Claus sulfur recovery integrated with advanced high temperature gas turbine; no solid waste generated
	15	Calderon Energy Company	Combined pyrolysis/gasifier system with lime bed hot gas cleanup to coproduce methanol and power
	33	Sunlaw Energy Corporation	Air blown IGT U-GAS fluid bed gasifier with in-bed sulfur removal and hot particulate removal followed by zinc ferrite final desulfurization
	35	M-C Power Corporation	IGT U-GAS fluid bed gasifier with in-bed sulfur removal; zinc ferrite final hot desulfurization integrated with a molten carbonate fuel cell
	53	Cool Water Coal Gasification Program	Oxygen blown slurry feed Texaco gasifiers with both radiant and quench cooling with MDEA gas cleaning and Claus sulfur recovery; advanced single pass liquid phase methanol reactor and byproduct aggregate production integrated with gas and steam turbine for power production; no solid waste generated
Miscellaneous	10	Frontier Energy Corporation	Coal/heavy oil hydrogenation plant
	55	Carbonic International, Inc.	Separation plant to capture CO_2 emissions

Exhibit 7

PROPOSED PROJECT SIZE AND DURATION BY TECHNOLOGY CATEGORY

Technology	No.	Proposer	Project Size	Duration (Months)
Advanced Combustion	23	Cogentrix/Coastal Joint Venture	110 MWe (cogen.)	47
	36	Coal Dynamics Corporation	15 MWe (gross)	48
	41	TransAlta Resources Investment Corporation	33 MWe	21
	47	Energy Partners, Inc.	6 tons/hr coal feed	36
	50	En-R-Tech International, Inc.	3 tons/hr coal feed	24
Coal Processing--Coal Preparation	44	CYCLEAN, INC.	NA	NA
	45	CLI Corporation	10 tons/hr coal feed	42
	46	Otisca Industries, Ltd.	40,000 dry tons/yr	24
Coal Processing--Fuel Upgrading	13	Western Energy Company	68 tons/hr coal feed	59
	26	Char-Fuels Associates, Ltd.	100 MWe	86
	42	Minnesota Power	50 tons/hr coal feed	NA
	52	K-Fuel Partnership	NA	NA
Combined Technologies	40	Virginia Electric and Power Company	125 MWe	90
	43	Duquesne Light Company	600 tons/hr coal feed	72

NA = Not available.

Exhibit 7 (Continued)

PROPOSED PROJECT SIZE AND DURATION BY TECHNOLOGY CATEGORY

Technology	No.	Proposer	Project Size	Duration (Months)
Flue Gas Cleanup--Combined SO_2/NO_x Control	9	Combustion Engineering, Inc. Snamprogetti U.S.A., Inc.	35 MWe	45
	11	The Babcock & Wilcox Company	5 MWe	37
	29	Montana State University	Lab scale	12
	34	NOXSO Corporation	65 MWe	49
	54	Helipump Corporation	1,000 ft^3/min	48
Flue Gas Cleanup--NO_x Control	2	Southern Company Services, Inc.	500 MWe	36
	3	Southern Company Services, Inc.	7.5 MWe	54
	4	Southern Company Services, Inc.	180 MWe	41
	5	Combustion Engineering, Inc.	108 MWe	50
	20	The Babcock & Wilcox Company	600 MWe	32
	21	The Babcock & Wilcox Company	100 MWe	43
	32	Ultrasystems Engineers & Constructors, Inc.	1.7 MWe	36
Flue Gas Cleanup--Sulfur Control (Injection)	6	Combustion Engineering, Inc.	180 MWe	64
	22	The Babcock & Wilcox Company	156 MWe	56
	24	Bechtel National, Inc.	140 MWe	24
Flue Gas Cleanup--Sulfur Control (Tailgas)	1	Southern Company Services, Inc.	100 MWe	82
	25	Pure Air	529 MWe	68
	48	Northern States Power Company	750 MWe	36

Exhibit 7 (Continued)

PROPOSED PROJECT SIZE AND DURATION BY TECHNOLOGY CATEGORY

Technology	No.	Proposer	Project Size	Duration (Months)
Fluidized-Bed Combustion--Atmospheric (Industrial)	12	Pedco, Inc.	0.625 ton/hr coal feed	48
	27	Southern Illinois University at Carbondale	3.5 MWe	60
Fluidized-Bed Combustion--Atmospheric (Utility)	14	City of Independence, Missouri	44 MWe repowering 54 MWe increment; Total 98 MWe	84
	16	Southwestern Public Service Company	256 MWe	72
	28	Tennessee Valley Authority	160 MWe	48
	30	Staley Continental, Inc.	55 MWe	45
	31	Tennessee Valley Authority	160 MWe	72
	38	Manitowoc Public Utilities	22 MWe	50
	39	Modular Power Plant Limited Partnership	17 MWe	84
	49	Lignite Research Council	200 MWe	NA
	51	City of Tallahassee, Florida	250 MWe	63
Fluidized-Bed Combustion--Pressurized	18	American Electric Power Service Corporation	330 MWe	95
	37	Allison Gas Turbine Division, General Motors Corporation	NA	NA
Industrial Processes	17	Passamaquoddy Tribe	11.4 tons/hr coal feed	36
	19	Bethlehem Steel Corporation	5,687 tons/hr coal feed	39

Exhibit 7 (Continued)

PROPOSED PROJECT SIZE AND DURATION BY TECHNOLOGY CATEGORY

Technology	No.	Proposer	Project Size	Duration (Months)
Integrated Gasification Combined Cycle	7	Combustion Engineering, Inc.	65 MWe	108
	8	Florida Power & Light Company	383 MWe	85
	15	Calderon Energy Company	87 MWe (net)	58
	33	Sunlaw Energy Corporation	94 MWe	87
	35	M-C Power Corporation	500 kWe	58
	53	Cool Water Coal Gasification Program	55 tons/hr maximum coal feed	48
Miscellaneous	10	Frontier Energy Corporation	1,128 tons/day coal feed	48
	55	Carbonic International, Inc.	NA	NA

Exhibit 8

GEOGRAPHIC LOCATION OF PROPOSERS AND PROJECTS

Technology	No.	Proposer	Proposer's State	Project Location County	Project Location State
Advanced Combustion	23	Cogentrix/Coastal Joint Venture	NC	James City	VA
	36	Coal Dynamics Corporation	PA	Fayette	PA
	41	TransAlta Resources Investment Corporation	Alberta, Canada	Williamson	IL
	47	Energy Partners, Inc.	DC	St. Clair	IL
	50	En-R-Tech International, Inc.	IL	Jackson	IL
Coal Processing--Coal Preparation	44	CYCLEAN, INC.	TX	Williamson	TX
	45	CLI Corporation	PA	Fayette	PA
	46	Otisca Industries, Ltd.	NY	Onondaga & Oneida	NY
Coal Processing--Fuel Upgrading	13	Western Energy Company	MT	Rosebud	MT
	26	Char-Fuels Associates, Ltd.	CO	Converse	WY
	42	Minnesota Power	MN	Itasca	MN
	52	K-Fuel Partnership	CO	Campbell	WY
Combined Technologies	40	Virginia Electric and Power Company	VA	Grant & Tucker	WV
	43	Duquesne Light Company	PA	Greene & Allegheny	PA

Exhibit 8 (Continued)

GEOGRAPHIC LOCATION OF PROPOSERS AND PROJECTS

Technology	No.	Proposer	Proposer's State	Project Location County	State
Flue Gas Cleanup--Combined SO_2/NO_x Control	9	Combustion Engineering, Inc. Snamprogetti U.S.A., Inc.	CT NY	Trumbull	OH
	11	The Babcock & Wilcox Company	OH	Belmont	OH
	29	Montana State University	MT	Gallatin	MT
	34	NOXSO Corporation	PA	Jefferson	OH
	54	Helipump Corporation	OH	Niagara	NY
Flue Gas Cleanup--NO_x Control	2	Southern Company Services, Inc.	AL	Floyd	GA
	3	Southern Company Services, Inc.	AL	Escambia	FL
	4	Southern Company Services, Inc.	AL	Bay	FL
	5	Combustion Engineering, Inc.	CT	Trumbull	OH
	20	The Babcock & Wilcox Company	OH	Jefferson	OH
	21	The Babcock & Wilcox Company	OH	Grant	WI
	32	Ultrasystems Engineers & Constructors, Inc.	CA	Montgomery	IL
Flue Gas Cleanup--Sulfur Control (Injection)	6	Combustion Engineering, Inc.	CT	York	VA
	22	The Babcock & Wilcox Company	OH	Belmont	OH
	24	Bechtel National, Inc.	CA	Indiana	PA
Flue Gas Cleanup--Sulfur Control (Tailgas)	1	Southern Company Services, Inc.	AL	Coweta & Carroll	GA
	25	Pure Air	PA	Lake	IN
	48	Northern States Power Company	MN	Sherburne	MN

Exhibit 8 (Continued)

GEOGRAPHIC LOCATION OF PROPOSERS AND PROJECTS

Technology	No.	Proposer	Proposer's State	Project Location County	Project Location State
Fluidized-Bed Combustion--Atmospheric (Industrial)	12	Pedco, Inc.	OH	Hamilton	OH
	27	Southern Illinois University at Carbondale	IL	Jackson	IL
Fluidized-Bed Combustion--Atmospheric (Utility)	14	City of Independence, Missouri	MO	Jackson	MO
	16	Southwestern Public Service Company	TX	Potter	TX
	28	Tennessee Valley Authority	TN	McCracken	KY
	30	Staley Continental, Inc.	IL	Macon	IL
	31	Tennessee Valley Authority	TN	McCracken	KY
	38	Manitowoc Public Utilities	WI	Manitowoc	WI
	39	Modular Power Plant Limited Partnership	NY	Indiana	PA
	49	Lignite Research Council	ND	Mercer	ND
	51	City of Tallahassee, Florida	FL	Leon	FL
Fluidized-Bed Combustion--Pressurized	18	American Electric Power Service Corporation	OH	Mason	WV
	37	Allison Gas Turbine Division, General Motors Corporation	IN	Madison	IL
Industrial Processes	17	Passamaquoddy Tribe	ME	Knox	ME
	19	Bethlehem Steel Corporation	PA	Baltimore	MD

Exhibit 8 (Continued)

GEOGRAPHIC LOCATION OF PROPOSERS AND PROJECTS

Technology	No.	Proposer	Proposer's State	Project Location County	Project Location State
Integrated Gasification Combined Cycle	7	Combustion Engineering, Inc.	CT	Sangamon	IL
	8	Florida Power & Light Company	FL	Martin	FL
	15	Calderon Energy Company	OH	Wood	OH
	33	Sunlaw Energy Corporation	CA	Champaign	IL
	35	M-C Power Corporation	IL	Cook	IL
	53	Cool Water Coal Gasification Program	CA	San Bernardino	CA
Miscellaneous	10	Frontier Energy Corporation	OH	Lake	OH
	55	Carbonic International, Inc.	FL	Orange	FL

Exhibit 9

SULFUR LEVELS IN COALS FOR UTILIZATION IN FUTURE COMMERCIAL APPLICATIONS

Technology	No.	Proposer	Sulfur Content of Coal High >3%	Medium 1-3%	Low <1%
Advanced Combustion	23	Cogentrix/Coastal Joint Venture	X	X	X
	36	Coal Dynamics Corporation	X	X	X
	41	TransAlta Resources Investment Corporation	X	X	X
	47	Energy Partners, Inc.	X	X	X
	50	En-R-Tech International, Inc.	X	X	X
Coal Processing--Coal Preparation	44	CYCLEAN, INC.	NA	NA	NA
	45	CLI Corporation	X	X	X
	46	Otisca Industries, Ltd.	X	X	X
Coal Processing--Fuel Upgrading	13	Western Energy Co.			X
	26	Char-Fuels Associates, Ltd.	X	X	X
	42	Minnesota Power			X
	52	K-Fuel Partnership			X
Combined Technologies	40	Virginia Electric and Power Company	X	X	X
	43	Duquesne Light Company	X	X	X

NA = Not Available
Blank space indicates that application does not target this type of coal.

Exhibit 9 (Continued)

SULFUR LEVELS IN COALS FOR UTILIZATION IN FUTURE COMMERCIAL APPLICATIONS

Technology	No.	Proposer	Sulfur Content of Coal High >3%	Medium 1-3%	Low <1%
Flue Gas Cleanup-- Combined SO_2/NO_x Control	9	Combustion Engineering, Inc., and Snamprogetti U.S.A., Inc.	X	X	X
	11	The Babcock & Wilcox Company	X	X	X
	29	Montana State University	NA	NA	NA
	34	NOXSO Corporation	X	X	X
	54	Helipump Corporation	X	X	X
Flue Gas Cleanup-- NO_x Control	2	Southern Company Services, Inc.		X	X
	3	Southern Company Services, Inc.	X	X	X
	4	Southern Company Services, Inc.		X	X
	5	Combustion Engineering, Inc.	X	X	X
	20	The Babcock & Wilcox Company	X	X	X
	21	The Babcock & Wilcox Company	X	X	X
	32	Ultrasystems Engineers & Constructors, Inc.	X	X	X
Flue Gas Cleanup-- Sulfur Control (Injection)	6	Combustion Engineering, Inc.	X	X	X
	22	The Babcock & Wilcox Company		X	X
	24	Bechtel National, Inc.	X	X	X

Exhibit 9 (Continued)

SULFUR LEVELS IN COALS FOR UTILIZATION IN FUTURE COMMERCIAL APPLICATIONS

Technology	No.	Proposer	Sulfur Content of Coal High >3%	Medium 1-3%	Low <1%
Flue Gas Cleanup-- Sulfur Control (Tailgas)	1	Southern Company Services, Inc.	X	X	X
	25	Pure Air	X	X	X
	48	Northern States Power Company	X	X	X
Fluidized Bed Combustion-- Atmospheric (Industrial)	12	Pedco, Inc.	X	X	X
	27	Southern Illinois University at Carbondale	X	X	X
Fluidized Bed Combustion-- Atmospheric (Utility)	14	City of Independence, Missouri	X	X	X
	16	Southwestern Public Service Company	X	X	X
	28	Tennessee Valley Authority	X	X	X
	30	Staley Continental, Inc.	X	X	X
	31	Tennessee Valley Authority	X	X	X
	38	Manitowoc Public Utilities	X	X	X
	39	Modular Power Plant Limited Partnership	X	X	X
	49	Lignite Research Council	X	X	X
	51	City of Tallahassee, Florida	X	X	X
Fluidized-Bed Combustion-- Pressurized	18	American Electric Power Service Corp.	X	X	X
	37	Allison Gas Turbine Division, General Motors Corporation	X	X	X

Exhibit 9 (Continued)

SULFUR LEVELS IN COALS FOR UTILIZATION IN FUTURE COMMERCIAL APPLICATIONS

Technology	No.	Proposer	Sulfur Content of Coal High >3%	Medium 1-3%	Low <1%
Industrial Processes	17	Passamaquoddy Tribe	X	X	X
	19	Bethlehem Steel Corporation		X	X
Integrated Gasification Combined Cycle	7	Combustion Engineering, Inc.	X	X	X
	8	Florida Power & Light Company	X	X	X
	15	Calderon Energy Company	X	X	X
	33	Sunlaw Energy Corporation	X	X	X
	35	M-C Power Corporation	X	X	X
	53	Cool Water Coal Gasification Program	X	X	X
Miscellaneous	10	Frontier Energy Corporation	X	X	
	55	Carbonic International, Inc.	X	X	X

Exhibit 10

SUMMARY OF ENVIRONMENTAL AND COMMERCIALIZATION CHARACTERISTICS

Technology Category	Date of Commercialization	Region of Application	Coal Type	Emissions Reduction (%) NO_x	SO_2
Advanced Combustion	1990-1993	National	Subbituminous	50-70	70-90
(slagging combustor)			Bituminous		
Coal Processing					
Coal Preparation (physical/chemical)	1990-1993	National	All ranks	0	0-90
Fuel Upgrading		Western U.S.	Subbituminous	0	0-20
Combined Technologies	1990-1995	National	All ranks	50-90	50-90
(coal preparation, combustion, post-combustion)					
Flue Gas Cleanup					
NO_x Control	1991-1995	National	All ranks	50-95	0-20
Sulfur Control--Injection	1991-1995			0	50-80
Sulfur Control--Tailgas	1991-1995			0	90-95
Combined SO_x/NO_x	1991-1995			50-90	50-95
Fluidized-Bed Combustion					
Atmospheric	1991-1995	National	All ranks	70-80	90-95
Pressurized				80-90	90-95
Industrial Processes	1991-1995	National	All ranks		>90
Integrated Gasification Combined-Cycle	1988-1993	National	All ranks	90-95	97-99
Coal/Oil Coprocessing	1995-1997	National	All ranks	90-95	95-97

V. Environmental Considerations

The ICCT Program has a strong environmental orientation. Its objective is to demonstrate technologies that, among other things, are capable of achieving significant reduction of SO_2 and NO_x emissions from existing coal-burning facilities, particularly those that contribute to transboundary and interstate pollution. A number of approaches have been implemented to keep environmental considerations an integral part of the ICCT demonstrations. These approaches involve two kinds of environmental activities. One involves the NEPA strategy, and the other involves monitoring environmental and health impacts and performance. These two types of activities are explained below.

NEPA STRATEGY

The overall strategy for compliance with NEPA includes both programmatic and project specific environmental impact considerations, during and subsequent to the selection process. However, an extremely tight schedule and confidentiality requirements have placed certain restrictions on the NEPA review. DOE is following the procedures described below to ensure that environmental factors are fully evaluated and integrated into the decision-making process to satisfy its NEPA responsibilities.

Offerors were required to submit both programmatic and project-specific environmental data and analyses as a discrete part of their proposal. DOE independently evaluated the environmental data and analyses submitted by offerors, to the maximum extent possible, and developed supplemental information and performed analyses as necessary to support reasoned decision-making. Major elements of the NEPA strategy are summarized below.

Programmatic Environmental Impact Analysis

DOE prepared a comparative programmatic environmental impact analysis, based on information provided by the offerors and supplemented by DOE, as necessary.[22] This environmental analysis was provided to the Source Selection Official to ensure that relevant environmental consequences of the ICCT Program and reasonable programmatic alternatives were evaluated in the selection process. The analysis included the maximum potential change in principal air emissions, water effluents, and solid wastes that might be produced regionally and nationally within the United States in the year 2010 if each technology proposed were to achieve its anticipated maximum U.S. market. The projected environmental impacts of anticipated commercialization of the candidate technologies were discussed. These discussions addressed, in qualitative terms and to the extent possible, unresolved environmental issues, identified areas where important environmental information is incomplete or unavailable, and evaluated tradeoffs between short-term and long-term effects.

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[22] *Innovative Clean Coal Technology Programmatic Environmental Impact Analysis*, U.S. Department of Energy, September 1988.

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Project-Specific Environmental Review

For proposals that underwent comprehensive evaluation, DOE prepared and considered, before the selection of proposals, an environmental impact analysis that focused on environmental issues pertinent to decision-making. The analysis summarized the strengths and weaknesses of each proposal against the environmental evaluation criteria, including (1) a discussion of alternative sites and/or processes reasonably available to the offeror, (2) a brief discussion of the environmental impacts of each proposal, (3) practical mitigating measures, and (4) a list of permits that must be obtained in implementing the proposal, to the extent known.

Post-Selection NEPA Review

Upon award of federal financial assistance, offerors are required to submit additional environmental information.[23] This detailed site and project-specific information will be used as the basis for site-specific NEPA documents to be prepared by DOE for each selected project. Such NEPA documents will be prepared, considered, and published in full conformance with the Council on Environmental Quality's NEPA regulations and in advance of a decision by DOE to share costs beyond preliminary design.[24] Federal funds from the ICCT Program will not be provided for detailed design, construction, operation, and/or dismantlement until the NEPA process has been completed successfully.

Selected offerors will prepare the necessary information and submit it to DOE in a self-contained *Volume of Environmental Information* which will include:

- A summary of environmental, health, safety, and socioeconomic information and analysis
- A description of the environmental setting of the proposed project, including a physical description of the project site and environmental conditions
- A description the project's facility requirements (e.g., resources and offsite facilities), overall plant site and setting, and plant/process residuals (e.g., discharges and waste storage)
- A discussion of the impacts and consequences of the project at the selected site and alternative sites, plans for offsetting such impacts, and a summary and ranking of the consequences according to risk to project implementation
- An identification and preliminary assessment of the major environmental laws and regulations (federal, state, and local) for which compliance will be necessary prior to implementation of the project

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[23] The required information was specified in Appendix J, "Information Requirements for the National Environmental Policy Act," of the ICCT PON.

[24] CEQ's NEPA regulations are in 40 CFR Parts 1500-1508; DOE guidelines were published in 45 *Federal Register* 20 (694), 1980.

- Information for assessing the project's impacts, if any, on water resource requirements and water availability.

ENVIRONMENTAL MONITORING REVIEW

DOE views the identification and characterization of areas of concern and the development of an information base for the assessment and mitigation of impacts associated with the replication of clean coal technology projects to be a fundamental purpose of environmental and health monitoring and an important component of the demonstration project. Monitoring should identify the environmental constraints and/or advantages of potential commercial versions of the demonstrated technology. In addition, environmental monitoring may be necessary to quantify the project-specific and site-specific environmental impacts predicted in the NEPA documentation, to detect any environmental and health problems requiring remedial action, and to confirm the performance of environmental mitigation measures implemented as part of the project. Towards these ends, DOE requires that the participant (i.e., selected offeror) perform a broad range of monitoring activities related to potential environmental and health impacts of the project and technology.

Monitoring activities are intended to ensure that significant technology, project, and site-specific environmental data are collected and disseminated in order to protect health, safety, and the environment. In addition to data required for compliance with environmental regulations and permits obtained from local, state, and other federal agencies, additional monitoring may be required to meet the following objectives:

- Ensure that emissions, ambient levels of pollutants, and environmental impacts do not exceed expectations projected in NEPA documents

- Identify any need for corrective actions

- Verify the performance of mitigating measures implemented in conjunction with the project.

Environmental data on performance of the technology is collected to provide a basis for assessing and mitigating any adverse impacts of future commercialization of the technology.

Environmental impacts of operations after completion of the ICCT demonstration phase, and, where appropriate, of disposition of the facility, also are considered by DOE, as required under NEPA. Depending on the results of the NEPA process, the participant may need to consider and analyze whether and to what degree monitoring is required to ensure that the continued safety and limitation of adverse environmental impacts, either resulting from the ICCT demonstration project or predicted in NEPA documentation, will be achieved following completion of the project.

Monitoring activities are documented in the form of an Environmental Monitoring Plan (EMP).[25] The EMP is developed, in consultation with DOE, in several stages. First, the

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[25] Guidelines for development of the EMP were provided in Appendix N, "Environmental Monitoring Plan Guidelines," of the ICCT PON.

participant is required to develop an EMP Outline (EMPO) and then the EMP. Both must be found acceptable to DOE by dates specified in the cooperative agreement. The EMP is subject to revision and updating as the project progresses. The EMPO and the EMP are described below.

Environmental Monitoring Plan Outline

The EMPO is a general description of the monitoring tasks and the rationale for the scope and types of monitoring proposed. It specifies the scope of the monitoring to be performed during each phase of the project. The EMPO includes a list of substances to be monitored, an indication of the general locations where measurements and monitoring will take place, and general types of sampling techniques with duration and frequency.

In the case of uncertainties about the generation of pollutants, their transport to media, or environmental effects, a phased approach to monitoring may be considered in which initial characterization and monitoring is used to determine the need and scope for further monitoring activities. The EMPO includes the participant's general approach to determining need and scope and the analyses, reports, decision milestones, and points for DOE review in the EMP.

Relevant information from the EMPO is included in the NEPA documentation prepared by DOE for each project and made publicly available.

Environmental Monitoring Plan

The EMP reflects additional monitoring requirements that may be identified in the NEPA process. The plan updates the general information in the EMPO and specifies the details regarding sampling locations, monitoring parameters, and sampling and analytical procedures. Development of the EMP is expected to take place along with the design of the project.

The EMP contains the following information:

- **EMP Purpose and Scope**--Definition of the overall approach to the monitoring and measurement activities

- **Project/Process Description**--Technology description, process flow diagrams, process and discharge streams, and pollution control systems

- **Environmental Characterization**--Plans for developing an information base for identification, assessment, and mitigation of environmental problems associated with the replication of the technology, including definition of the parameters that establish process operating conditions and determine environmental discharge characteristics

- **Compliance Monitoring**--Identification of permits, conditions of permits, and monitoring requirements of permits in terms of type of monitoring and timing

- **Supplemental Environmental Impact Monitoring**--Specific monitoring plans to identify and confirm environmental impacts and performance predicted in the NEPA documentation, including monitoring to establish that predicted impacts have not been exceeded and that mitigating measures are performing satisfactorily

- **Integration of Monitoring Activities**--A break down of specific monitoring activities by project phases and monitoring media to avoid redundancy in the monitoring

- **Data Management and Reporting**--Description of the data management system to be used, reporting schedule, report contents and format, and types of analyses.

Categories of Monitoring

The EMP specifically addresses three categories, or classes, of monitoring which serve as a basis for systematic planning and analysis. The three classes are:

- **Class I: Environmental Characterization Monitoring**--This class is intended to develop the information base for identification, assessment, and mitigation of environmental problems associated with replication of the technology. It addresses the environmental characteristics of the clean coal technology and associated facilities, processes, and activities. Activities may include measurements of feedstocks, operating conditions, discharges, ambient environmental conditions, and impacts on health and ecological systems. Environmental characterization emphasizes the special attributes of the technology and pollutants specific to it, rather than attributes common to existing commercial technologies. The participant is required to identify the salient process and operating parameters that are likely to affect environmental discharge rates and compositions, waste generation, and other relevant environmental characteristics of construction and operation. The EMP shows how information about parameters is reported and related to analyses of the monitoring data. Monitoring of ambient environmental concentrations and impacts is required where necessary to assist characterization of the source and/or to assess the transport and effects of pollutants or other impacts of the technology that are poorly understood.

- **Class II: Compliance Monitoring**--Compliance monitoring is the monitoring required by other agencies of the federal, state, and local government to satisfy statutes and regulations concerning the environment and occupational and public health and safety, and terms of leases, permits, grants, and other requirements. The EMP documents the extent of compliance monitoring activities, shows their relationship to Class I and III objectives, and outlines the reporting of relevant results to DOE.

- **Class III: Supplemental Environmental Impact Monitoring**--Supplemental monitoring addresses the potential need to identify and quantify environmental impacts predicted in NEPA documentation and to confirm the performance of mitigating measures. It deals with project-specific and site-specific environmental impacts. The participant is required to analyze the monitoring needed to identify and confirm potential environmental and health impacts identified in the project environmental information furnished and in subsequent NEPA documentation.

The EMPO and EMP must include an analysis and justification for the level and type of monitoring proposed, including the case of no additional monitoring. While compliance monitoring is likely to satisfy Class III objectives in most cases, there may be special monitoring needs to ensure that potential environmental impacts will not occur or to ensure the performance of mitigation measures. These special needs may arise in the course of the NEPA process, resulting in additional monitoring requirements.

For planning purposes, monitoring activities are cross-referenced to these three categories of objectives. While some overlap may occur among the monitoring, data analysis, and reporting activities, unnecessary redundancy of actual monitoring is minimized. Monitoring activities are integrated among the three categories of objectives and across different media, and activities are correlated. Different types of monitoring data are interrelated in terms of their spatial and temporal relationships and integrated with operational data for purposes of planning, data analysis, and reporting. Furthermore, the participant is encouraged to include in the EMPO and EMP a section dealing specifically with such integration issues.

APPENDIX A
TECHNOLOGY DESCRIPTIONS

ADVANCED COMBUSTORS

Description

A coal combustor is a device in which coal and oxygen are combined or burned to produce usable heat (thermal energy). In the context of the DOE program in Advanced Combustion Technology, coal combustors include those devices which can be added or used to retrofit an existing furnace or boiler and entirely new, stand-alone combustion devices.

Combustors in varying sizes and configurations have been used by the industrial and utility sectors for years. However, the full realization of their performance potential has been limited by environmental constraints imposed by the New Source Performance Standards (NSPS). The high operating temperatures necessary for improved thermal efficiency invariably have resulted in the production of unacceptable levels of nitrogen oxides (NO_x), while their use with high-sulfur coals has produced unacceptable levels of sulfur oxides (SO_x).

An advanced combustor is a device that will control or remove sulfur, nitrogen oxides, and particulate matter from coal-derived fuel before combustion gases are injected into retrofitted oil or gas boilers or heaters, or will meet emissions requirements as a stand-alone combustion device. Although these combustors primarily are intended for retrofit applications, they also will be applicable and appropriate for incorporation into the design of new facilities that utilize their compact size and flexibility with regard to the types of coal that can be used. Typical of these projects is the advanced slagging combustor effort which seeks to control: (1) particulate emissions by converting ash into molten slag which is removed before injection into the boiler or heater, (2) NO_x formation by staged combustion to suppress temperatures, and (3) SO_x formation by the injection of alkali compounds during combustion. In advanced stages of development, these slagging combustors are suitable for incorporation either in new designs or in large retrofit applications in the heavy industrial and utility market (50 million Btu per hour or greater) in boilers and both direct and indirect process heaters. Research also is in progress to develop advanced combustors for light industrial, commercial, and residential sectors.

Environmental Characteristics

Advanced combustion technologies reduce emissions in the combustion process through advanced combustor design, boiler modification, or the introduction of sorbents into the combustor. Additional removal can be achieved by using coal preparation before combustion or an alternative coal-based fuel to reduce sulfur and ash in the fuel to be fired.

One advanced combustion technology under development involves slagging cyclone combustors that offer the potential to reduce SO_2 emissions by 70-90 percent when burning coal. This reduction is achieved by introducing limestone or some other sorbent into the combustor or into the combustion gases exiting the combustor after the slagging stage. A high degree of slag and sulfur capture in the same stage have proved difficult to achieve.

If a sorbent is injected into the hot combustion gases, or if significant amounts of sorbent are carried into the boiler, SO_2 is captured in the particulate cleanup system of the boiler. In general, a baghouse or electrostatic precipitator (ESP) is used to remove particulates from the products of combustion. Between 80 and 90 percent of the ash can be rejected as slag. NO_x is reduced in the slagging cyclone combustor by combustion staging (i.e., the combustor is operated sub-stoichiometrically, with combustion being completed in the boiler, where additional air is introduced). Overall, NO_x can be reduced by 50-70 percent relative to wall-fired, pulverized-coal combustors. Slagging combustors also have the potential to replace existing cyclone boilers, which are very high NO_x emitters, and where technological alternatives for achieving NO_x reductions on existing cyclone boilers are limited because they cannot be fitted with commercially available low-NO_x burners.

Other technologies can be used in advanced combustion systems to achieve environmental goals. Deep physical coal cleaning prior to combustion generally can reduce sulfur emissions by 40-60 percent (depending on the ratio of pyritic to organic sulfur in the coal), without the need for capital-intensive modification to the boiler. Particulate emissions can be reduced because the ash flowing into the ESP or baghouse is reduced; however, ash composition (and gas composition) can be affected, which might decrease ESP efficiency. Reburning in the boiler in conjunction with the staged cyclone combustor can further reduce NO_x.

The use of coal mixtures could further enhance the attractiveness of advanced combustors by providing an acceptable method for storing, handling, and feeding fuel. Because the production of coal-water mixtures involves fine grinding, thereby lending itself to deep benefication, the use of coal-water mixtures in advanced combustors could further improve the environmental performance of advance combustors.

Status of Development and Work in Progress

Current methods of burning coal to produce usable thermal energy include:

1. Circular and cell burners used on conventional pulverized coal boilers of up to 165 million Btu per hour.

2. Spreader stokers which direct coal into the furnace over a fire bed with a uniform spreading action, permitting the fine particles to burn in suspension as the larger particles fall to the grate for combustion in a fast burning bed.

3. Underfed stokers in which coal is fed from a hopper by a reciprocating ram to a central section called a retort. Conveying mechanisms move the coal upward in a spreading motion over the air inlets (called tuyeres) where it is burned with the ash passing on to a dumping grate.

4. Water-cooled and vibrating stokers which consist of a tuyere grate surface mounted on, and in contact with, a grid of water tubes interconnected with the boiler's circulating systems for positive cooling. Coal is fed to the grate where it is burned as it passes along the grate to the rear of the stoker, where ash is dumped into an ash pit.

5. Traveling grate stokers in which the entire grate moves, acting as an endless belt on which the coal burns as it is conveyed to the rear of the furnace where the ash is dumped.

6. Cyclone combustors which use crushed rather than pulverized coal and which complete the combustion process outside the boiler. Air is injected into the combustor tangentially, imparting a swirling motion to the incoming coal. Ash is fused in the combustion process and removed from the combustor as molten slag.

Cyclone combustors can use the abundant and relatively inexpensive surplus of high-sulfur, high-ash, low-fusion-temperature coals. Recent developments have shown that such combustors can operate in a staged manner to control the formation of NO_x during the combustion process while still rejecting most of the ash as slag. These capabilities of cyclone combustors have resulted in a renewed interest in this technology by DOE's Advanced Combustion Technology Research Program.

DEPARTMENT OF ENERGY PROGRAM

The current research and development (R&D) program was initiated to develop advanced combustion technology for use in light industrial, commercial, and residential applications. In late 1986 and 1987, DOE awarded 13 contracts which comprise the current Advanced Combustion Technology Research Program. The 13 awards are listed below by application and concept.

Retrofit:

- Babcock & Wilcox/Cyclone Retrofit for Industrial Boilers (Slagging)
- Combustion Engineering, Inc./High-Efficiency Coal Combustion System
- TRW, Inc./Advanced Industrial Combustion System.

Light Industrial:

- Management and Technical Consultants, Inc. (MTCI)/Pulse Coal Combustor (Resonance Tube) for Industrial Boilers and Heaters
- University of Tennessee Space Institute (UTSI)/Coal Combustion System for Industrial Boilers
- Vortec Corporation/Coal-Fired Glass Melting Process Heater
- Otisca Industries/Development of a Burner Management System and Flame Safety Standards.

Commercial:

- Catholic University/Vertical Vortexing Combustor for Space/Water Heating Applications (Cold Flow Modeling)
- U.S. Navy Civil Engineering Laboratory/Vertical Vortexing Combustor for Space/Water Heating Applications (Hot Testing).

Residential:

- o Management and Technical Consultants, Inc. (MTCI)/Coal-Fired Pulse Combustor (Resonance Tube) for Residential Space Heating
- o Energy and Environmental Research, Inc. (EER)/Coal-Fueled Combustor for Residential Space Heating
- o Tecogen, Inc./CWM-Fired Residential Warm Air/Hot Water Heating System
- o AVCO Research Laboratory/Pulsed Coal Combustor (L-Star) for Residential Space Heating.

Four of these contracts (TRW, MTCI/Industrial, UTSI, and Vortec) also have application to large industrial and/or utility systems.

PROJECTS IN PROGRESS

The DOE report of February 1987, *America's Clean Coal Commitment*, identified a nationwide inventory of clean coal technology development and demonstration projects receiving significant public or private sector funding in the 1986-1992 time interval. The inventory identifies three projects in the advanced combustors technology category; descriptions are provided in Appendix B of the aforementioned report. The projects are listed below.

Projects in Progress

No.	Project	Site
3	Coal Tech Corporation/Slagging Combustor with Sorbent Injection into Combustor	Williamsport, PA
21	Scio Pottery Co./Industrial Cogeneration	Scio, OH
23	Hudepohl Brewery Power House/Industrial Rotary Cascading Bed Boiler	Cincinnati, OH

Source: *America's Clean Coal Commitment* (DOE/FE-0083), U.S. Department of Energy, February 1987.

Relationship between the R&D Program and CCT-I

Two advanced combustion projects are included in the Clean Coal Technology Demonstration Program (i.e., CCT-I):

- o Coal Tech Corporation/Advanced Cyclone Combustor Demonstration Project
- o TRW, Inc./Advanced Slagging Coal Combustor Utility Demonstration Project

Coal Tech's advanced cyclone combustor will be demonstrated for industrial and utility applications. *The combustor is an air-cooled cyclone combustor of the slagging type.* SO_x control is achieved by injecting limestone with coal into the burner. NO_x control is achieved by operating the first combustion stage with an oxygen deficiency. Ash and particulates are controlled through slag capture.

Under the R&D program, 40 hours of testing were completed on Coal Tech Corporation's 30-million-Btu-per-hour, air-cooled, cyclone combustor. This test involved firing a coal-water mixture and established the startup and shakedown data to support a 1,000-hour test using dry pulverized coal under the CCT-I.

TRW's advanced slagging combustor will be demonstrated at a scale suitable for utility applications. The project involves converting an existing reheat-type utility boiler from oil to coal, while meeting environmental standards and without derating the unit. Limestone will be injected into the combustion gases before they are sent to the boiler. To enhance sulfur capture, a lime recycling system will be installed and tested.

This project will extend TRW's demonstration of its slagging coal combustor from the small industrial boiler demonstration (40 MMBtu per hour) to a full-scale utility boiler retrofit demonstration, using four 160-MMBtu-per-hour combustors. A boiler in an Orange and Rockland Utilities power plant located at Stony Point, NY, will be retrofitted with the four combustors.

Applicability of the Technology to Retrofitting, Repowering, or Modernizing Existing Facilities

Advanced combustion technology offers the capability for retrofitting large industrial and utility boilers that are oil-, gas-, or coal-fired. Retrofitting large coal-fired boilers with advanced combustors can reduce emissions of acid rain precursors. Additionally, retrofitting can extend the life of the boiler or heat exchanger because the gases entering the boiler are cleaner. Retrofitting is primarily applicable to industrial and utility boilers; for smaller applications replacement is likely to be more appropriate.

Advanced combustion technology has the potential of replacing oil- and gas-fired combustion units in large residential and commercial applications. These combustors are new units and are designed to replace an existing oil- or gas-fired unit.

COAL PREPARATION

Description

Coal preparation and waste recovery processes utilize technologies to separate the ash-forming mineral matter and sulfur from coal and from high-carbon residues respectively. Excess moisture may also be removed from lower rank coals. These impurities or unwanted constituents vary widely from coal seam to coal seam as well as from coal to coal. As a result, cleaning technology and economics are closely linked to the specific feed coal. In addition to removing sulfur and ash, the preparation process crushes and grinds the coal to provide the customer with a product improved in quality and consistency over the as-mined coal. Advanced coal cleaning techniques have the potential to provide a much cleaner coal which could be utilized in new markets, with significant applications additional to the now dominant utility and large industrial markets.

Coal preparation (or benefication) processes can be classified into two broad categories: (1) physical preparation and cleaning and (2) chemical/biological cleaning. The commercial practice of coal cleaning currently is limited to physical separation of the impurities based on differences in the specific gravity and mass of coal constituents (e.g., gravity separation processes such as jigs, heavy media cyclones, tables, etc.) and the differences in surface properties of the coal and its mineral matter content (e.g., froth flotation). These physical coal cleaning processes can remove up to about 50 percent of the total sulfur with thermal recoveries over 80 percent, depending upon the characteristics of the specific coal being processed.

Physical coal cleaning methods can be very effective in removing pyritic sulfur and mineral matter from coal. The more finely coal is ground, the greater is the liberation of impurities not chemically bound to the coal matrix. However, when coal is ground to fine sizes (between 28-325 mesh) and ultrafine sizes (finer than 325 mesh) conventional physical cleaning techniques become progressively more difficult and less effective. Also, physical cleaning methods leave untouched the organic, chemically bound sulfur. Newer approaches to physically cleaning finely ground coal use special additives and unique flotation cell designs to remove even more mineral matter and pyritic sulfur. Electrostatic techniques to clean dry coal are also under development. This technology relies on inducing charges of opposite polarity on coal particles and particles of mineral matter to accomplish separation.

Both pyritic and chemically bound organic sulfur are converted to SO_2 when coal is burned. Because existing physical cleaning technology removes only the pyritic sulfur contained in the mineral matter, research is under way on advanced chemical and biological techniques to remove organically bound sulfur. Chemical treatment has the potential to remove (1) virtually all pyritic sulfur, including finely divided and dispersed pyritic sulfur that may not be removed by physical treatment, (2) a significant portion of the organically bound sulfur, and (3) virtually all the associated mineral matter. Organic sulfur removal is of particular importance because it represents, on average, about one-third to one-half of the total sulfur in domestic coals. Research on chemical cleaning methods and modification of coal shows considerable technical potential for removing nearly all of the ash and both forms of sulfur. At this stage of development, however, the costs of chemically cleaning coal are much greater per ton of product than costs associated with conventional coal cleaning technology.

Environmental Characteristics

Coal cleaning technology is becoming more important to coal producers, utilities, industrial customers, and to the public as the search continues for cost-effective means of reducing emissions of SO_2. For a coal user, clean coal can increase the efficiency of, or reduce the requirement for, post-combustion emission controls such as flue gas desulfurization (scrubbers).

Utility and large industrial boilers that, because of their age, are not required to meet New Source Performance Standards, burn significant amounts of medium- and high-sulfur coal which may produce emissions of up to 4 pounds of SO_2 per million Btu. For much of this coal, over 60 percent of the total sulfur is in pyritic form, thus susceptible to removal by deep physical coal cleaning techniques. The remaining sulfur is organic in nature and requires other techniques, including chemical treatment, for removal.

Commercial, as well as advanced, physical coal preparation processes (described elsewhere in this section) produce a reject stream consisting chiefly of ash (clays and pyrites, which are iron sulfide compounds) with varying amounts of residual coal.

When chemicals are used in a coal benefication process, the environmental requirements are process- and site-specific. Process economics, as well as environmental concerns, dictate that those chemicals which are not consumed be recovered and recycled. Various chemicals (for example, hydrocarbons) may be used to control the surface properties of particles of coal and minerals to affect separation characteristics and the final degree of physical cleaning. Chemical benefication technologies being developed can remove organic as well as pyritic sulfur by treating the coal with inorganic caustic solutions and acids. These chemicals are recovered and regenerated, and any residue in the coal product is neutralized.

Pyritic sulfur, removed by physical coal cleaning processes, is not changed in chemical form, and remains in the ash as insoluble iron and sulfur compounds. However, sulfur removed by chemical treatment is usually converted to gaseous hydrogen sulfide or to a water-soluble sulfate which can then be converted to useful forms, such as fertilizer and elemental sulfur.

As new processes are developed, process and waste streams are characterized so that appropriate environmental controls can be incorporated into the final process configuration.

Status of Development and Work in Progress

The status of the various coal preparation technologies ranges from those currently used by industry (as in the case of some physical benefication processes) to advanced research concepts being explored in laboratory settings (as in the case of microbial treatments). Current research and development investigations range from pilot plant efforts sponsored by industrial groups (such as Homer City Coal Quality Development Center) to proprietary process development in industrial research centers and laboratory investigations by universities and government laboratories.

DEPARTMENT OF ENERGY PROGRAM

DOE is a major sponsor of both physical and chemical coal preparation research. Some of the work is performed in-house at DOE's Pittsburgh Energy Technology Center. Research indicates that coal from advanced cleaning processes will burn more cleanly than most coals currently fired in industrial boilers or industrial processes, and existing boilers, with or without modifications, will be able to accept coals cleaned by advanced cleaning methods. As advanced coal cleaning technologies are further developed and commercialized, more U.S. coals will be cleaned. Coal preparation techniques will be applicable to both new and retrofit installations. Descriptions of DOE-sponsored work in progress follow. These activities include (1) physical benefication, (2) chemical and biological benefication, and (3) support studies and ancillary operations (explained below).

Physical Benefication

Advanced physical coal cleaning methods of interest are focused primarily on the potential for increased cleaning efficiency of ultrafine coal (finer than 325 mesh). Laboratory float-sink tests indicate the theoretical potential to remove over 90 percent of both ash forming minerals and pyritic sulfur from ultrafine coal. This is a significant improvement over results with a coarse coal feed. DOE and the Electric Power Research Institute (EPRI) are cooperating in selecting and developing coal cleaning technologies for testing at the Coal Quality Development Center operated by EPRI at Homer City, Pennsylvania. The technologies for grinding ultrafine coal and processing or handling the clean product are being considered at the same time. The Pittsburgh Energy Technology Center (PETC) has found that advanced physical coal cleaning techniques could play a cost-effective role in reducing SO_2 emissions from pre-NSPS utility boilers. To facilitate near-term commercialization, the Clean Coal Research Initiative (CCRI) was established in 1988. This initiative focuses on the most promising three technologies: selective coalescence, heavy liquid cycloning, and microbubble flotation. The intent of CCRI is to conduct the necessary research and engineering development to bring these three technologies to commercial viability by 1992. The status of the technologies supported by DOE are summarized below:

1. Heavy Liquid Cyclone--In this process a heavy liquid (typically an organic chemical) is used to effect separation of mineral matter from the coal in a cyclone. Separation can be achieved for a wide range of coal particle sizes using a heavy liquid intermediate in specific gravity between the coal and the impurities. Development of commercial applications based on using this heavy liquid cyclone technique to clean ultrafine coal has been hampered by recovery system cost, liquid loss, liquid toxicity, corrosiveness, and other factors. However, recent developments have demonstrated that many of these problems can be mitigated. Continued investigations are appropriate for evaluating process operating parameters to establish viability at this scale and the potential viability of the process at commercial scale. This technology is being developed further by CCRI.

2. Froth Flotation--This technique for physical coal cleaning takes advantage of differences in surface properties of particles in an aqueous slurry to achieve separation. Coal is generally more hydrophobic than its impurities and can be floated to the surface by finely dispersed air bubbles and removed as cleaned product, while the more hydrophilic mineral matter particles sink and are removed as waste. A frothing agent and collector may be used to facilitate removal of the coal particles. This technology is widely used in industry today

to beneficiate moderately fine coal. However, current state-of-the-art technology does a poor job of separating ultrafine particles. Further laboratory research is required on understanding and modifying the surface properties of these particles and on novel systems for achieving efficient separation.

Research has shown great promise for using microbubbles to enhance the separation efficiency of very fine particles. Work is continuing at the laboratory scale, as well as at the proof-of-concept scale, to determine the viability of microbubble technology in novel flotation circuits and devices. This technology is also a commercialization candidate under CCRI.

3. Selective Coalescence--In this application, an agglomerating agent in a turbulent aqueous phase takes advantage of differences in surface properties between coal and its impurities to agglomerate (or coalesce) coal particles while the impurities remain suspended in the water. At ultrafine coal sizes, the liberation of impurities is greatly improved over that with coarser particles. Laboratory tests have shown excellent ash removal efficiency, but removal of pyritic sulfur particles is not necessarily good with current selective coalescence techniques. The DOE program includes research on the basic physical mechanisms that are involved in this phenomenon and on novel, non-aqueous media such as liquid carbon dioxide, which has demonstrated the potential of yielding exceptionally high energy recoveries (greater than 96 percent) with better than 90 percent ash and pyritic sulfur removal. Testing of a liquid carbon dioxide bench-scale unit has been completed. Laboratory research to better understand the basic mechanisms of selective coalescence is being continued. In addition, the commercialization data base for this technology is being developed under CCRI.

4. Electrostatic/Magnetic Separation--Electric and/or magnetic fields can be applied to fine coal as a means to separate coal from its impurities. Differences in electric charge together with differences in magnetic susceptibility cause the mineral matter and the coal to separate when passed through these fields. Past research on magnetic separation has been marginally successful because of the low-level magnetic susceptibility of the mineral matter. New research efforts have been initiated to investigate electrostatic and electrostatically enhanced magnetic separation.

Chemical Benefication

Organic sulfur in coal is chemically bound to the coal, thereby requiring a chemical (or biochemical) reaction to separate it from the coal matrix. Promising coal preparation technology areas that employ chemical reactions in some way have been identified and are currently being pursued. The current status of these areas is summarized below:

1. Molten-Caustic Leaching--In this process finely ground coal particles are exposed to a molten caustic. This exposure results in chemical leaching which can remove over 90 percent of the total sulfur and mineral matter from the coal. The cleaned coal can then be separated from the spent caustic and impurities through water washing and filtration. The spent caustic is separated from contaminants and regenerated for reuse. Favorable test results have been obtained at the bench scale of each of the modules that could comprise an integrated, continuously operating system. A bench-scale integrated unit to demonstrate the feasibility of continuously operating such a system is ready

for testing in 1988 and 1989. An improved estimate will be made of the economics of this method of chemical cleaning when data become available.

2. Pretreatment of Coal to Improve "Cleanability"--Historically, coal cleaning to remove ash has been applied to run-of-mine coal which had only been physically modified (ground and screened) prior to physical cleaning. Past research has attempted to determine if specific physical changes to the coal, such as specialized grinding or electrostatic charging, could be used to enhance the ability of subsequent cleaning technologies to remove mineral matter and sulfur. The objective of the current research is to identify chemical modifications to coal or char that would result in enhanced "cleanability" of the resultant solid stream from various feed coals.

Biological Benefication

Biological approaches to coal preparation represent some of the most innovative and advanced efforts currently being considered. In theory, biological processes offer the potential of achieving essentially complete sulfur removal at conditions of ambient or near ambient operation, and with low energy requirements. At the same time, process development difficulties (e.g., process control, media/microbial systems stability, product consistency) present significant problems in research and development.

Success in microbial desulfurization (using bacteria in the laboratory to remove organic sulfur from coal) has recently been reported. The development of bacterial desulfurization processes requires highly specific bacterial cultures having the desired performance characteristics (e.g., sulfur removal efficiency, growth rate, reliability in process conditions). Current activity focuses on the isolation of naturally occurring bacterial strains. In addition, there is at least one instance of developing a microorganism with improved characteristics through mutagenic alteration of the microbes. Preliminary bench-scale work to investigate the validity of this concept is currently being carried out under this program. If the results of this effort continue to be promising, further research should be undertaken.

Other biological approaches involve exploration of non-bacterial systems (e.g., fungal systems for benefication of low rank coals). In addition to direct use of microbes in *in vivo* coal processing systems, other processes have been proposed which would employ microbial growth in batch systems, followed by extraction of desired enzymes and injection of enzyme extract into the *in vitro* coal processing systems. Such two-stage process approaches could allow for potential advantages in both biological process control and in reduction of the residence time required in the coal cleaning systems.

Support Studies and Ancillary Operations

As research continues on advanced concepts for cleaning coal, parallel research on problems and techniques that are common to many of the benefication processes can make significant contributions to generally advancing the state of the coal cleaning art.

As coal is ground finer to liberate more mineral matter, analysis and characterization of the coal components become more difficult. The ability to characterize feed coal and cleaned coal accurately and quickly is important to the coal industry, but is dependent upon the development of sophisticated techniques, especially for micron-sized particles.

Coal grinding, which is an ancillary operation to coal cleaning, requires a large amount of costly energy and desirable ultra-fine grinding requires even more energy. Since grinding and cleaning are usually accomplished in an aqueous medium, special techniques are required for dewatering finely ground coal and coal product. Special techniques also are required to remove excess water, as well as ash, from certain low rank coals, and the coal product should not readily absorb moisture after the initial drying phase. These are the research areas supported by DOE under the catch-all heading of "Support Studies and Ancillary Operations."

PRIVATE SECTOR PROGRAM

Industrial research and development efforts are focused largely on physical coal cleaning improvements, specially flotation techniques, cycloning, and agglomeration. EPRI supports a number of coal cleaning projects related to requirements of the electric utility industry. At Homer City, Pennsylvania, EPRI operates a coal cleaning test facility and DOE cooperates with EPRI in testing advanced concepts at this site. A number of companies are investigating improvements in existing technology. Commercial coal cleaning facilities are operated by coal producers or by large coal customers, particularly electric utilities.

PROJECTS IN PROGRESS

The DOE report of February 1987, *America's Clean Coal Commitment*, identified a nationwide inventory of clean coal technology development and demonstration projects receiving significant public and/or private funding in the 1986-1992 time interval. There is one project in the coal preparation technology category; a description is provided in Appendix B of the aforementioned report. The project is listed below.

Project in Progress

No.	Project	Site
26	EPRI Coal Cleaning Test Facility	Homer City, PA

Source: *America's Clean Coal Commitment* (DOE/FE-0083), U.S. Department of Energy, February 1987.

Relationship between the R&D Program and CCT-I

There are no specific coal preparation projects included in CCT-I. Nevertheless, many of the selected projects plan to utilize commercially cleaned coal. The coal preparation program is developing new and improved processes that can be integrated into any system to improve the performance of coal combustors and post-combustion flue gas cleanup, thereby removing more sulfur emissions and reducing solid waste at the combustion site.

Applicability of the Technology to Retrofitting, Repowering, or Modernizing Existing Facilities

A coal preparation plant is normally a stand-alone unit which can be constructed at mine mouth, at a central processing point, or at a customer's facility. Physically and technically a coal cleaning facility can readily be used to retrofit, repower, or modernize existing facilities, space permitting.

In order to optimize the economic and technical contribution of a planned coal cleaning plant to utility operation, for example, an analysis of the overall cleaning facility plus power plant system is necessary. The feed coal must be considered in selecting the cleaning technology and major pieces of equipment. Also some assurance is required that the cleaned coal product is a satisfactory fuel for the existing, or planned, combustion equipment. The final emissions of sulfur dioxide and particulates will be controlled by adjusting downstream cleanup to take advantage of the cleaner coal feed. The system's operating cost and/or emissions will be reduced if the components are properly integrated. These benefits can be achieved with a properly integrated coal cleaning facility providing a fuel of lower ash and sulfur content. Such a clean fuel may reduce the transportation costs and will lower erosion and corrosion of boiler tubes, reduce the generation of waste on site, and improve the efficiency and reliability of the boiler plant. The requirement for post-combustion cleanup will be reduced or possibly eliminated under certain conditions.

Coal preparation technology also can be used at locations where high carbon-content residues or reject materials are available to reduce the ash and sulfur content of those residues, thereby increasing the supply of cleaner fuel.

FLUIDIZED-BED COMBUSTION

Description

Fluidized-bed combustion (FBC) technology derives its name from the vigorous agitation or "fluidization" that takes place inside a boiler. The technology comprises two broad categories: (1) atmospheric fluidized-bed (AFB) combustion, which operates at or near atmospheric pressure on the fireside, and (2) pressurized fluidized-bed (PFB) combustion, which operates at a fireside pressure of 90-200 pounds per square inch (gauge). An FBC boiler is a combustion chamber for converting the chemical energy of coal or waste products into thermal energy for process heat, steam, or electricity. FBC boilers offer two major advantages over conventional stoker-fired and pulverized-coal boilers: (1) control of SO_2 and low-NO_x emissions within the combustion chamber, thereby eliminating the need for scrubbers, NO_x control burners, or elaborate combustion modifications, and (2) fuel flexibility allowing the burning of a range of solid fuels with widely varying ash, sulfur, and moisture contents.

In a fluidized bed, solid, liquid, and/or gaseous fuel, together with inert material (for example silica sand, alumina, or ash from the fuel), are kept suspended in a combustion chamber through the action of fluidizing air distributed below the bed. The fluidization state can be achieved through either the bubbling-bed or circulating-bed concept. The bubbling-bed concept attempts to reduce solids carry-over by maintaining a low fluidization velocity within the combustor. The circulating-bed concept allows high solids carry-over through high-velocity air which entrains and returns the solids to the combustor for additional burning.

Environmental Characteristics

Fluidized-bed combustion technologies burn coal to produce steam and/or electricity for utility and industrial use while reducing SO_2 or NO_x emissions within the combustor. Fluidized-bed combustion for both AFB and PFB provides *in situ* SO_2 and NO_x emissions control. The operating temperature of the combustion process is well below the thermal NO_x formation point. The injection of a carbonate sorbent (calcite or dolomite) into the bed of the combustor results in the capture of SO_2 released during the combustion process. The only downstream pollution control equipment needed is for particulate matter. DOE data from numerous operating hours show that FBC technology readily meets current NO_x and SO_2 standards and that existing New Source Performance Standards for particulate emissions can be met using an electrostatic precipitator or fabric filter.

The secondary environmental impacts associated with FBC are similar to those of conventional coal combustion. The FBC processes generate an inert dry solid waste material containing coal ash, unused sorbent (calcined limestone), and spent sorbent (calcium sulfate). This waste is removed from the process as spent bed material along with the collected particulate matter and may be easily disposed of in landfills or possibly can be sold for industrial or agricultural applications.

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Status of Development and Work in Progress

ATMOSPHERIC FLUIDIZED-BED COMBUSTION

AFB technology is commercially available now for large industrial boiler applications (200,000 lbs/hr steam and greater). Commercial units are offered by 17 U.S. boiler manufacturers, and approximately 130 units are either operating or committed to construction. However, economic applications of fluidized-bed combustion in the smaller sizes that are required for light industrial and commercial/institutional applications are not commercially available. AFB systems in these size ranges would allow coal to be substituted for oil and gas in these important market sectors. The major emphasis of DOE's current AFB program is to develop AFB technology for these market applications.

Department of Energy Program

The objective of DOE's AFB program is to develop the smaller systems technology by 1992 so that the private sector can demonstrate and commercialize coal-fired AFB systems for the industrial, commercial, and residential sectors that are capable of economically generating process steam, indirect and direct heating, and on-site electric power as a means of displacing oil and gas.

The AFB program consists of the following major elements: (1) industrial applications, (2) advanced concepts, (3) special applications, and (4) technology development, each of which is explained below:

1. Industrial Applications--Demonstration units (Rivesville, Georgetown, Shamokin, Great Lakes, Wilkes-Barre, and East Stroudsburg) were supported in industries with large potential uses for the technology. These units, co-funded by DOE, were operated by industry and illustrated performance in the host industry. Work in industrial applications is essentially complete. All that remains is some monitoring, collecting, and evaluating of operational results from the demonstration units. This will expand the data base for determining technical, economic, and environmental characteristics.

2. Advanced Concepts--To broaden market penetration into the industrial sector (75,000-200,000 lbs/hr steam), AFB concepts are needed that offer significant improvements in economics and performance. Such advanced concepts designs have been evaluated, and two (Kellogg and Battelle) are being tested for the potential to reduce capital costs to 20-30 percent less than those for conventional FBC systems. Bench-scale testing for the Kellogg concept was completed in September 1986. Bench testing of the Battelle concept is scheduled for completion in December 1988.

   In 1988, two new contractors (Riley Stoker and York Shipley) were selected under a competitive solicitation to develop new advanced concepts. Work on these projects will continue the effort to address the application of atmospheric fluidized-bed technology to the small boiler market. In June 1988, Good Samaritan Hospital, in conjunction with Skelly and Loy, York Shipley, and the Pennsylvania State University, was funded to develop a coal-burning FBC hospital waste incinerator.

3. Special Application--Projects involve market analyses, system and economic studies, and design and testing of special AFB applications. The focus is primarily on light industrial, commercial, and institutional applications that are less than 50,000 lbs/hr steam. In 1988, four contractors were selected under a competitive solicitation to develop concepts for special applications. Each project includes market analysis, system and economic studies, and testing through proof-of-concept of an innovative AFBC design.

4. Technology Development--Activities provide the basic system support needed to advance and broaden the state-of-the-art of AFB. Technology development is aimed at investigating, testing, and analyzing technical issues and data for AFB technology and providing research and development support for prototype systems so that industry can efficiently undertake commercialization.

Private Sector Program

The Electric Power Research Institute (EPRI) has taken the initiative in adapting AFB to utility scale. The three utility demonstrations of AFB supported by EPRI are listed below:

1. Colorado-Ute, Nucla Station, 110 MW--A new circulating fluidized-bed boiler was built to repower an existing 36-MW steam turbine/generator and power a new 74-MW steam turbine/generator. The plant achieved full load operation in March 1988. Parties involved in this project included Colorado-Ute, Pyropower, Stearns Catalytic, Peabody Coal, Westinghouse, EPRI, and the National Rural Electric Cooperative Association. DOE completed negotiations resulting in the project's inclusion in CCT-I.

2. Northern States Power, Black Dog Station, 125 MW--This retrofit of an existing 100-MW pulverized coal boiler, upgraded to 125 MW with a bubbling fluidized-bed design, became operational in 1986. Participants include Northern States Power, Foster Wheeler, Stone and Webster, and EPRI.

3. Tennessee Valley Authority, Shawnee Station, 160 MW--A new AFB boiler is being used to repower and extend the life of an existing 160 MW steam turbine generator through the installation of a bubbling fluidized-bed design partially supported by DOE. Full-scale operation is anticipated in January 1989.

Additionally, a new 150-MW circulating fluidized-bed combustion boiler system with an external heat exchanger is under construction in Robertson, Texas for Texas-New Mexico Power. This utility plant is scheduled to be operational in January 1990.

Industrial applications have also been demonstrated. A 190,000-lbs/hr steam circulating AFB unit has been in operation at a California Portland Cement Company plant since 1985. Other AFB units in excess of 300,000 lbs/hr steam are being used by Archer-Daniels-Midland, General Motors, Scott Paper, Westwood Energy, Gilberton Power Company, Signal, A.E. Staley, and Fort Howard Paper.

PRESSURIZED FLUIDIZED-BED COMBUSTION

The objectives of DOE's PFB Program are to (1) develop a U.S. technology base for scientific and engineering technology data to support private sector efforts to demonstrate and commercialize the first PFB systems for electric power generation in the early 1990s, and (2) extend the state-of-the-art by developing advanced PFB concepts. The goals desired are substantial improvements in cycle performance (approaching 45 percent), and at least 20 percent reduction in the cost of electricity as compared with the cost from conventional coal-fired power plants with flue gas desulfurization.

The PFB process is not as technically mature as AFB. Significant research and development has been conducted on PFB, however, and work has progressed to the point where sufficient data are available to design and construct a prototype PFB coal-fired demonstration plant. If all goes according to plan, industry should be able to proceed with pilot scale testing by the mid- to late-1990s.

Department of Energy Program

DOE's 10-year-old research and development program in PFB has made significant progress. Major advantages of the technology have been identified, and industry is now moving to build prototype systems which will lead to commercialization.

The research and development activities supporting the program are embodied in two categories:

1. PFB Technology Base--Projects are being aimed at developing a U.S. technology base, through proof-of-concept, to support private sector efforts to demonstrate and commercialize prototype PFB systems for electric power generation. Current PFB activities supporting the development of these prototype systems are summarized below.

   o Follow-on work at Grimethorpe in the United Kingdom (U.K.) involved developing pilot scale data on combustor performance, using a coal-slurry feed system and an updated, U.S.-designed heat-exchanger tube-bundle furnished by Foster Wheeler Development Corporation. Additionally, DOE will obtain project "core" data from the National Coal Board (U.K.)-funded program as well as data from an advanced hot gas cleanup device provided for the project by EPRI.

   o The New York University test facility evaluated components, and tested and evaluated design alterations and changes in operating parameters which enhance process combustion and environmental performance. The facility also conducted proof-of-concept testing of advanced hot gas cleanup devices.

   o Metal wastage studies at the Morgantown Energy Technology Center (METC) and other organizations include erosion/corrosion (in-bed heat exchangers, gas turbine blades) experimental testing and predictive modeling.

   o METC in-house activities include systems evaluation, PFB data base activities, combustion performance, and testing of in-house reactors (both hot and cold).

2. Second Generation, Advanced Cycle Concepts--Foster Wheeler has intitated a multiphased project consisting of conceptual designs and cost estimates, experimental testing of key critical process components (pyrolyzer, circulating

PFB, cross-flow filter, and topping combustor), and operating and evaluating an integrated subpilot test facility.

Private Sector Program

EPRI is characterizing several PFB cycles with the goal of identifying and recommending a program to accelerate technology demonstration. EPRI is also participating in the Grimethorpe effort by providing funding for the design and testing of an advanced hot gas cleanup device.

The American Electric Power Service Corporation Teamed with ABB-STAL and Babcock & Wilcox in a program which is constructing a PFB demonstration plant at the Tidd Station near Brilliant, Ohio. As part of the program, the team completed operation of a component test facility in Malmo, Sweden, to verify boiler design conditions projected for the Tidd Plant.

The City of Stockholm completed a design study and has initiated construction of a PFB boiler installation at a nearby cogeneration plant. It will produce 235 MW heat and generate 133 MW electricity using two PFB modules supplied by ASEA-PFB. Additionally, ASEA-PFB has initiated construction of a 79 MWe PFB combined-cycle power plant for ENDESA at its Escatron Station near Madrid, Spain.

The United Kindgom joined with West Germany and the U.S. in cofunding the International Energy Agency (IEA)/Grimethorpe project. In the United Kingdom, other principal PFB developments were achieved at the Coal Utilization Research Laboratory (CURL) facility which included several small test units. These were used in DOE-sponsored coal-water slurry and elevated pressure (20 atm) combustion test programs. The CURL facility has been dismantled, and the 20-atm testing unit was relocated to the National Coal Board's Stoke Orchard (U.K.) facility.

PROJECTS IN PROGRESS

The DOE report of February 1987, *America's Clean Coal Commitment*, identified a nationwide inventory of clean coal technology development and demonstration projects receiving significant public or private funding in the 1986-1992 time interval. There are 14 projects in the fluidized-bed combustion technology category; descriptions are provided in Appendix B of the aforementioned report. A list of the projects follows.

Projects in Progress

No.	Project	Site
1	American Electric Power Service Corp./Pressurized Fluidized-Bed Combustion Combined Cycle Utility	Brilliant, OH
14	Tennessee Valley Authority/160-MW Atmospheric Fluidized-Bed Combustion Demonstration Plant	Paducah, KY
15	20-MW Atmospheric Fluidized-Bed Combustion Pilot Plant	Paducah, KY
18	Anderson Clayton Foods Co./Dual Fluidized-Bed Boiler Retrofit	Jacksonville, IL

19	Archer-Daniels-Midland/108-MW Circulating Fluidized-Bed Cogenerators (5)	Decator, IL
24	Northern States Power/Atmospheric Fluidized-Bed Combustion Utility Conversion (Black Dog Unit No. 2)	Minneapolis, MN
25	Colorado-Ute/Circulating Atmospheric Fluidized-Bed Demonstration Plant	Nucla, CO
31	Wisconsin Electric Power Company/Atmospheric Fluidized-Bed Retrofit of Four Coal-Fired Units (500 MW Total)	Oak Creek, WI
32	Texas-New Mexico Power Company/Circulating Utility Retrofit Fluidized-Bed Boiler	TBD (expected in Robertson Co., TX)
33	General Motors Corporation/27-MW Circulating Fluidized-Bed Cogeneration Unit	Pontiac, MI
34	Gilberton Power Company/Anthracite-Culm-Fired Cogeneration Plant	West Mahanoy Township, PA
35	Combustion Engineering & Lurgi Corp./27-MW Circulating Fluidized-Bed Cogeneration Plant	Reading, PA
36	Air Products & Chemicals, Inc./49-MW Circulating Fluidized-Bed Cogeneration Plant	Stockton, CA
37	Applied Energy Services/180-MW Circulating Fluidized-Bed Cogeneration Plant	Montville, CT

Source: *America's Clean Coal Commitment* (DOE/FE-0083), U.S. Department of Energy, February 1987.

In addition, two projects have been identified in Europe:

- o SEP/ASEA-PFBC 130-MWe and 210-MWt Bubbling Bed PFBC Cogeneration Plant (Stockholm, Sweden).

- o Endesa/ASEA-PFBC and BWE/79-MWe Bubbling Bed PFBC Power Generation (Madrid, Spain).

Relationship between the R&D Program and CCT-I

Under CCT-I, as an extension of their earlier work described in the previous section, the American Electric Power Service Corporation has been selected to demonstrate a utility application of PFB combined cycle technology at the Tidd Station near Brilliant, Ohio. The project will retrofit the coal-fired power plant (no longer in use) to construct a 70-MW PFB combined-cycle demonstration plant. The plant will operate at 1580 °F and 12 atmospheres, with gases expanded through a turbine with a steam turbine bottoming cycle. The project will use technology developed by ASEA-PFB and marketed in the U.S. by ASEA Babcock PFBC (a joint venture between ASEA and Babcock & Wilcox).

Boiler design conditions for this demonstration project were verified at the team's Malmo, Sweden, test facility. Test data obtained from operation of the IEA/Grimethorpe project confirmed results of the Malmo tests. The current Grimethorpe program will provide data on coal/sorbent slurry feeding and combustion characterization using an updated, U.S.-designed, in-bed heat-exchanger tube-bundle. This technical information will be used in the detailed designing of the Tidd Station demonstration.

Applicability of the Technology to Retrofitting, Repowering, or Modernizing Existing Facilities

ATMOSPHERIC FLUIDIZED-BED COMBUSTION

AFB technology offers the capability for retrofitting and repowering existing utility and industrial boilers. Benefits include emissions reductions, capacity increase, and plant modernization (life extension). Maximum use could be made of existing equipment, thereby saving the capital costs of building a new plant. Additionally, retrofitting would shorten construction time and greatly reduce the time required for permit and regulatory approval.

Retrofitting and/or repowering can be accomplished by either boiler replacement or modification. The Colorado-Ute, Nucla Station, is an example of boiler replacement; three existing stoker-fired boilers were replaced with a circulating fluidized-bed boiler. An example of boiler modification is the Northern States Power Project at the Black Dog Station (Minnesota). By retrofitting the Black Dog unit, which was designed for pulverized coal, the utility gained additional electric generating capacity while extending the life of a 35 year-old plant for an additional 25 years of operation. The project also resulted in considerable reduction in SO_x and NO_x emissions as well as providing increased flexibility for burning numerous lower cost fuels. Additionally, the utility realized extremely favorable economic advantages because the cost of retrofitting was approximately one-quarter of the cost of a new pulverized coal-fired unit with a wet scrubber.

PRESSURIZED FLUIDIZED-BED COMBUSTION

PFB technology offers the capability to repower oil- and gas-fired boiler units (while switching them to direct high sulfur coal-burning) and to retrofit and/or repower existing coal-fired power plants. The American Electric Power Service Corporation's Tidd Station project is an example of retrofitting and repowering with PFB technology. The power plant's existing pulverized coal-fired boiler will be replaced with a pressurized fluidized-bed combustor. Gas turbine for combined cycle operation will also be added. The resulting efficiency will be greater than for a pulverized coal-fired unit with flue gas desulfurization. In addition, repowering results in benefits such as maximum use of existing equipment, services, and sites, which saves capital costs, shortens construction schedules, and greatly reduces the time cycle for permit and regulatory approvals needed for a new power plant.

FUEL CELLS

Description

Fuel cells directly transform the chemical energy of a fuel (e.g., synthesis gas, reformed natural gas, reformed distillate fuel) and an oxidant (oxygen) into electrical energy. Each fuel cell includes an anode and a cathode separated by an electrolyte layer. In a typical fuel cell, fuel is supplied to the anode and air is supplied to the cathode to produce electricity, heat, and water.

Energy conversion in fuel cells is potentially more efficient (40-60 percent, depending on fuel and type of fuel cell) than traditional energy conversion devices. This is because fuel cells are not constrained by Carnot-cycle limitations and because electricity is generated directly in the fuel cell instead of going through an intermediate conversion step (i.e., burner, boiler, turbines, and generators). The fuel system efficiency can be increased further in cogeneration by using the byproduct heat of the reaction to generate steam to heat water.

Coal is a target fuel for fuel cell power plants. A typical fuel cell system using coal as fuel would include a coal gasifier with a gas cleanup system, a fuel cell to generate electricity (direct current), a power processing section to convert direct current to alternating current, and a heat recovery system. The heat recovery system would be used to capture rejected thermal energy to produce additional electrical power in a bottoming cycle.

Environmental Characteristics

Fuel cells require very clean fuel to avoid contamination and degradation of performance; their tolerance to sulfur, particulate matter, and other contaminants is very low. Hence, during operation, emissions from fuel cells of air pollutants, suspended solids, solid wastes, and contaminated waste water are insignificant. The level of emissions from an integrated fuel cell/gasification combined-cycle system are similar to those emitted from coal gasification combined-cycle systems, except that combustion of the gas does not occur so NO_x and SO_x production is negligible.

Status of Development and Work in Progress

The development of fuel cells in the United States has been under way for the past 25 years for high-technology applications such as the space program. During the 1970s, utilities began to investigate fuel cells as a potentially efficient, non-polluting alternative for generating power to meet load growth.

DOE is developing three types of fuel cells using different electrolytes: (1) phosphoric acid, (2) molten carbonate, and (3) solid oxide. Phosphoric acid systems are the most mature of these fuel cell systems and have the largest private-sector investment to date.

Within DOE's Phosphoric Acid Fuel Cell Program, two fuel cell applications are being emphasized: (1) electric utility systems and (2) on-site integrated energy systems. These two systems are designed for different sized applications, with the electric utility

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systems being in the multi-MW size range and the on-site systems in the 40-400-kW size range. Over 50 units of commercial prototype, phosphoric acid fuel cell (PAFC) power plants (200 kW) have been ordered and are expected to be ready for delivery by the end of the 1980s.

To date, PAFCs have been fueled by natural gas or naphtha, which is reformed to produce a hydrogen-rich fuel prior to being fed to the cell. Ongoing activities in PAFC development are described below:

1. International Fuel Cells Corporation (IFC), supported by DOE and EPRI, is completing the development of a commercial prototype 11-MW power plant. This would be the first fuel cell power plant intended for entry into the electric utility market.

2. Westinghouse, with DOE support, is also developing PAFC technology for utility power plants but is in an earlier stage of development than IFC. The present focus of the Westinghouse effort is on verifying fuel cell stack development goals and achieving the required performance and endurance levels in scaling up to the 100-kW-size stacks planned for the commercial prototype 7.5-MW power plant. The required short-term performance has been demonstrated in multiple laboratory stacks of up to 32 kW. The Westinghouse effort is focused on developing a commercial scale 7.5-MW power plant with cofunding from the private sector.

3. DOE and the Gas Research Institute (GRI) have cofunded work to develop fuel cells for commercial and industrial applications. Under this program, IFC has made 46 field test installations of pre-prototype 40-kW on-site units for various applications. The DOE-GRI test program, completed in 1986, accumulated more than 350,000 operating hours of experience. The technical and economic data gathered from this program have been used to determine the most likely markets, applications, and unique design features for a commercial, on-site PAFC unit. Further development of technology for PAFC on-site applications is being performed by IFC.

The early commercial PAFC power plants are expected to operate on reformed natural gas or distillate fuels. Operating experience with these fuel cells is expected to pave the way for coal-based molten carbonate and solid oxide fuels that will operate at higher efficiencies.

While methane-fueled PAFC power plants are expected to have efficiencies of roughly 45-50 percent, coal-based molten carbonate fuel cell (MCFC) and solid oxide fuel cell (SOFC) power plants are anticipated to have efficiencies in the range of 50-55 percent. MCFC technology is currently in the early development stage and scale-up to full area stacks is in progress. Short stacks of up to 25 kW have been tested. Improvements are needed in cell life and tolerance to fuel contaminants such as sulfur. SOFC technology has been tested in single cells and in 3- and 5-kW modules. Improvements in solid oxide cell fabrication techniques and cell materials are needed to achieve repeatable long life. SOFC tolerance to sulfur in the fuel appears higher than that for other types of fuel cells, but more work is required to take full advantage of this feature. Molten carbonate and solid oxide fuel cells are not expected to reach the commercialization stage until about the year 2000.

PROJECTS IN PROGRESS

Although the DOE report, *America's Clean Coal Commitment*, of February 1987, did not list any projects in the fuel cells technology category, fuel cell technology development and demonstration projects are being pursued in the United States under a variety of government and industry initiatives. Research is supported by DOE's Office of Fossil Energy under both the Office of Oil, Gas, Shale, and Special Technologies and the Advanced Research and Technology Development Program. Fuel cell research and demonstrations are also being supported by electric and gas utilities and utility organizations such as EPRI and GRI. Equipment manufacturers such as IFC, Westinghouse, and ERC are also pursuing active technology development programs.

Relationship between the R&D Program and CCT-I

There are no projects relating specifically to fuel cells among the demonstration projects comprising CCT-I.

Applicability of the Technology to Retrofitting, Repowering, or Modernizing Existing Facilities

While a gas-fueled phosphoric acid fuel cell system is a possible candidate for retrofitting oil-fired, gas-fired, or coal-fired utility boilers for peaking and intermediate duty, more advanced fuel cell systems may supersede these applications. Future repowering applications of PAFC, MCFC, or SOFC fuel cells could potentially include the staged addition of fuel cells to the capacity mix. Being inherently modular, fuel cells are suited for incremental expansion or as replacements for older boilers and turbines. Whether fuel cells are employed in retrofitting or repowering applications, they are expected to deliver power to the utility grid at a higher efficiency than existing boiler and turbine equipment.

FLUE GAS CLEANUP

Description

Currently available options for SO_2 control during coal utilization consist primarily of physical coal cleaning, switching to low-sulfur coal, and flue gas cleanup. Each has associated advantages and disadvantages. Physical coal cleaning is already in wide practice where it is presently economic to do so. However, the capability to reduce significantly the sulfur content of coals by conventional coal preparation is limited because only some of the inorganic sulfur contained in the mineral portion of the coal can be removed.

Switching to low-sulfur coals, although likely to be the lowest cost option available, also has a number of potential disadvantages. Analyses show that the high-sulfur coal industry would be severely affected. Fuel costs could increase both as a result of greater demand as well as higher transportation costs. Coal characteristics such as hardness, ash content, and heating value also differ from one coal to another, which could result in problems such as exceeding particulate control standards and causing plant derating. Substantial plant modifications could be necessary in order to compensate for the different characteristics of low-sulfur coal.

The third major approach is to clean the flue gases. Flue gas cleanup technology involves control of SO_x, NO_x, and particulate emissions released during coal combustion. In the case of SO_x (mainly sulfur dioxide with a few percent of sulfur trioxide), many processes have been proposed as ways to reduce their concentrations in combustion gases. As a general rule, these processes can remove 80-90 percent of the sulfur oxides from combustion flue gases containing 0.2-0.3 percent of these oxides. Flue gas treatment processes may be divided into two broad categories: wet and dry, depending upon whether the SO_2 absorbent is in a liquid or dry solid form. The processes can also be divided further into non-regenerative and regenerative types.

In wet processes, SO_x is removed from the flue gases by scrubbing with an aqueous solution or slurry. To avoid vaporizing the water and associated problems, the gas must be cooled before it enters the scrubber. Several different types of scrubbers have been designed to achieve intimate contact between the gas and the scrubbing (absorbing) liquid. Although liquid-gas scrubbing is simple in principal, several problems arise in practice. These problems include deposition of scale, especially with a slurry scrubber; blockage or plugging of the demister; and corrosion and erosion of the equipment.

The equipment for dry desulfurization of flue gases is generally simpler than the equipment used for wet scrubbing. However, reaction of SO_x with a dry sorbent generally is slower than with a solution or even a slurry. To overcome this drawback, dry scrubbers may be larger in size in order to expose a large surface area of solid absorbent to the flue gases.

The new flue gas cleanup technologies that are under development and/or demonstration can be divided in two generic process categories: (1) dry sorbent injection and (2) post-combustion gas cleanup. The first category, dry sorbent injection, involves the injection of a dry SO_2 sorbent such as limestone or hydrated lime directly into the combustion zone to capture SO_2 *in situ*. The second category, post-combustion gas cleanup, involves the reaction of sorbents in slurry, aqueous liquor, or dry powder form in the combustion gas stream downstream of the boiler to capture SO_2 following combustion.

In NO_x control, work to date has focused on combustion modification (air staging) and flue gas treatment. Both approaches have now been commercialized. Air staging is characterized by low cost but has limited potential (on the order of 50-60 percent maximum NO_x removal). Flue gas treatment, on the other hand, offers high effectiveness but with costs that are presently considered prohibitive in the United States. Recently, increased emphasis has been placed on another approach to combustion modification termed variously as reburning, fuel staging, or in-furnace NO_x reduction. The process involves the injection of fuel into combustion gases, followed, after a suitable residence time, by the addition of sufficient air at a somewhat lower temperature (roughly 1000 °C) to complete the combustion process. Modifying the combustion process in this manner destroys NO_x contained in the original combustion stream.

The reburning process is very complex. The potential for NO_x reduction appears to be a function of a relatively large number of process parameters, including temperature, relative fuel split between the primary combustion zone and the reburning zone, primary and reburning zone air-to-fuel ratios, gas residence time in the reburning zone, and the nitrogen content of the reburning fuel. If not correctly implemented, NO_x can actually be generated in the reburning zone from the reburning of fuel-bound nitrogen. In addition, the potential exists for reducing combustion efficiency as the result of incomplete fuel combustion. To realize the full potential of this technology, further research is required to improve understanding of the mechanisms involved, identify the free radical species of primary interest, and enhance the generation of these free radical species.

Some work is also being supported on the development of novel cleanup processes with the capability of simultaneously removing 90 percent of both SO_2 and NO_x. Some of the processes under development include the electron beam/ammonia, fluidized-bed copper oxide, moving-bed copper oxide, NOXSO, and a modified lime spray dryer approach.

Environmental Characteristics

Currently available post-combustion cleanup technologies for SO_2 control essentially consist of using either wet limestone scrubbers or lime spray dryers. Wet limestone-based scrubber processes are most commonly used because limestone is much less expensive than alternative reagents, such as lime; and the cost differential becomes magnified as the sulfur content of the coal increases. The increasing use of forced oxidation in conjunction with limestone scrubbing generates a gypsum product that is readily dewatered and negates many of the problems associated with the handling and disposal of a thixotropic sulfite sludge. The potential also exists for reducing capital cost through elimination of dewatering equipment. Utilities must, however, cope with the fly ash disposal problem, which is compounded by the flue gas desulfurization (FGD) waste disposal problem. Limestone scrubbers are effective (in excess of 90 percent SO_2 control) but are relatively expensive to purchase and operate. Reliability and availability have also been problem areas in addition to the waste handling and disposal.

The spray dryer can offer advantages over the commercially available limestone scrubbers especially for retrofitting where space requirements and land available for waste disposal can limit the application of wet scrubbers, or where remaining boiler life is low. Spray dryers generally have lower capital costs than scrubbers. The spray dryer cleanup systems capture SO_2 by contacting the hot flue gas with a finely atomized lime slurry in a spray dryer vessel. The water in the slurry is evaporated by the heat in the flue gas and the SO_2 reacts with the lime to form a dry calcium sulfite/sulfate products. The solid product plus ash is collected in the electrostatic precipitator (ESP) or baghouse. The resulting dry solids product is more manageable than the sludges produced in many wet scrubbing processes. These solids can be disposed of in suitable landfills. If high concentrations of unreacted alkalis remain, however, special consideration may be needed in its disposal. It should be noted also that application of the lime spray dryer processes to high-sulfur coals is in a relatively early stage of development, although it can now be considered commercially proven for use with low-sulfur western coal. More compact and somewhat less complex than the wet limestone scrubbers, the spray dryer's economic advantages over limestone scrubbers decrease with increasing coal sulfur content as a result of higher reagent costs.

Regenerable scrubbing processes do not produce a throwaway solid waste, but instead produce salable products such as elemental sulfur or sulfuric acid. In the dry sorbent approach, a solid absorbent is used to absorb SO_2 and NO_x. Upon regeneration at higher temperatures using a reducing gas, sulfur and nitrogen compounds are stripped off. These compounds are subsequently destroyed or converted to salable products using commercially available technologies. Consequently, regenerable systems avoid the growing problem of disposal of the solid wastes experienced by traditional flue gas cleanup technologies.

Status of Development and Work in Progress

DRY SORBENT INJECTION

The limestone injection multistage burner (LIMB) is an emerging technology that is currently undergoing research and development at the bench, pilot, prototype, and demonstration plant levels. The thrust of ongoing research is to identify those factors that govern system performance so that the removal efficiency can be optimized. An important aspect of this goal is the normalization of all site-specific factors to develop widely applicable process designs.

The Environmental Protection Agency (EPA), EPRI, DOE, and private industry are funding research being conducted by domestic and international boiler suppliers to optimize low-NO_x combustion/alkali injection techniques. Several major test programs have been completed or are being contemplated to conduct the following:

1. EPA is supporting major demonstrations. A commercial-scale demonstration of LIMB on a wall-fired boiler is now in progress. A project cofunded with EPRI also is in progress that will lead to a prototype-scale LIMB demonstration on a tangentially fired boiler. A project for a full-scale tangentially fired LIMB demonstration is also under way.

2. DOE funded a test of sorbent injection on a pulverized coal boiler using low-sulfur western coal. Preliminary analysis of the data showed favorable results.

3. Conoco funded testing on an industrial pulverized coal boiler. The demonstration yielded favorable results with respect to performance objectives. Further testing was also performed on sorbent injection in the duct upstream of the ESP.

4. Internationally, a number of countries are conducting research. Two significant contributors are Canada and West Germany; three jointly funded test programs have been completed or are under way in Canada, and two commercial LIMB facilities were placed in service in West Germany.

POST-COMBUSTION GAS CLEANUP

Advances in post-combustion gas cleanup are being made with respect to both process improvements and advanced processes. These improvements and processes can be applied to new plants or can retrofit existing facilities if space and economic constraints permit.

Numerous activities are being conducted by both the private and public sectors to improve the operation of existing emissions control systems. These process improvement activities include the following:

1. For existing FGD systems, research efforts focus on the use of organic acids or magnesium salts to enhance SO_2 removal efficiency and reagent utilization. Results indicate that a removal efficiency of 95 percent can be achieved at reduced operating costs.

2. For existing and new FGD systems, research is being conducted on reducing fresh water consumption and cleaning up wastewater discharges. The private sector, in conjunction with EPRI, is conducting research to reduce FGD water consumption, including recycling, biological control, and integrated water systems for power plants.

3. For SO_2 control, a promising low-cost of FGD option is dry injection of sodium-based sorbents in the flue gas before the fabric filter. EPRI has demonstrated this process, which is applicable to both new and existing low-sulfur coal facilities, in a full-scale facility. Additional research is proceeding on high-sulfur coal applications for use with ESPs for improved waste fixation and disposal, for system optimization, and for use with lower cost alternative reagents. Based on the success of this process development, a 112-MW commercial-scale demonstration was conducted at the Colorado Springs R.D. Nixon Plant, and the Public Service Company of Colorado has announced the use of a dry injection system for a new 500-MW coal-fired unit.

4. In the area of NO_x control, most of the work to date has focused on combustion modification (air staging) and flue gas treatment. Both approaches have now been commercialized. Reburning is being evaluated in the United States and Japan. Experimental results suggest that the combination of reburning with conventional air staging can result in NO_x reduction levels approaching those now attainable only through relatively expensive flue gas treatment processes.

5. For particulate control, research efforts are centered on performance improvement and optimization. In response to concerns related to trace element and inhalable particulate emissions, substantial emphasis is being placed on the removal of submicron-sized particles. Examples of these research efforts include electrostatic, electromagnetic, and sonic horn augmentation for fabric filtration; two-stage ESP; and use of additives.

In the area of advanced processes, significant long-term research is currently under way *in combined SO_2/NO_x control, SO_2 control, NO_x control, and particulate control* as described below.

1. Research and development activities in combined SO_2/NO_x flue gas cleanup are focusing on the development of processes capable of simultaneously controlling SO_2 and NO_x at the 90 percent level. Some of the relatively more mature processes that have been or are under development include: (1) electron beam/ammonia injection, (2) fluidized-bed copper oxides, (3) NOXSO, and (4) a modified lime spray dryer approach. The current development status of these technologies ranges from bench-scale to proof-of-concept. Additional process concepts currently in the early laboratory stage of development include the moving-bed copper oxide, electrochemical and membrane-based removal processes.

2. For advanced SO_2 control technologies, the primary emphasis is on reagent regeneration and salable product processes to eliminate or minimize solid waste disposal problems. The Flakt Boliden (sodium citrate reagent) and CONOSOX (potassium salt reagent) processes are in pilot-scale development, with commercial availability projected for the late 1990s. Advanced limestone/gypsum FGD processes, which produce marketable gypsum through forced oxidation of the spent slurry, are being developed for application in the United States. A 23-MW prototype of the Chiyoda Thoroughbred 121 process was successfully tested.

3. For post-combustion NO_x control, the selective catalytic and selective noncatalytic reduction systems are the most advanced. Pilot-scale systems of these two technologies have been tested on coal-fired power plants and found to be effective. However, these processes are more expensive than combustion modification, and major improvements are needed in the process control subsystem, extension of catalyst life, and elimination of ammonia leakage.

4. In the area of particulate control, DOE has a number of projects under way to improve the capability for removing respirable particulates. Approaches being pursued include acoustic agglomeration, particle precharging, centrifugal separation, and chemical conditioning.

PROJECTS IN PROGRESS

The DOE report of February 1987, *America's Clean Coal Commitment*, identified a nationwide inventory of clean coal technology development and demonstration projects receiving significant public or private funding in the 1986-1992 time interval. There are eight projects in the flue gas cleanup technology category; descriptions are provided in Appendix B of the aforementioned report. The projects are listed in the following table.

Projects in Progress

No.	Project	Site
2	Babcock & Wilcox Co./Tests of Limestone Injection Multistage Burner and Sorbent Duct Injection	Lorain, OH
4	Energy & Environmental Research Corp./Reburning & Sorbent Injection in Utility Boilers	Springfield, Hennepin, & Bartonville, IL
10	Commonwealth Edison/Copper Oxide Regenerable Flue Gas Desulfurization System	Kincaid, IL
16	TVA Spray Dryer/Electrostatic Precipitator Pollution Control Device	Paducah, KY
17	University of Illinois/Wet Flue Gas Desulfurization System	Champaign, IL
20	Babcock & Wilcox Co. (Ohio Edison's Toronto Station)/ Post-combustion SO_2 Control	Jefferson, OH
22	Columbia Gas System Corp./Catalytic Reduction Process for Coal Flue Gas	Columbus, OH
27	New York Electric and Gas/High Sulfur Test Center	Somerset Station, Niagara, NY

Source: *America's Clean Coal Commitment* (DOE/FE-0083), U.S. Department of Energy, February 1987.

Relationship between the R&D Program and CCT-I

The first successful full-scale testing of hydrated lime in furnace sorbent injection processes was accomplished under the DOE research and development program in flue gas cleanup. The use of hydrated lime has since been adapted by the Babcock & Wilcox Company and Energy and Environmental Research Corporation in CCT-I projects. The hydrate addition at low temperature (HALT) process currently being developed under the DOE Flue Gas Cleanup Program will provide important data to the Coolside process being used by the Babcock & Wilcox Company and to the duct injection process for SO_2 control in cyclone furnaces being used by the Energy and Environmental Research Corporation.

In return, test facilities being developed in these two CCT-I projects could provide for future full-scale demonstration of technologies under development in DOE's Flue Gas Cleanup Program. Technologies that could be demonstrated include advanced reburning concepts for NO_x control, improved boiler sorbents for SO_x control, and in-duct injection of hydrated lime slurries.

Applicability of the Technology to Retrofitting, Repowering, or Modernizing Existing Facilities

Dry-sorbent-based processes, such as furnace injection (LIMB) and duct injection (Coolside), have been conceived primarily with retrofitting in mind. Duct injection of hydrated lime slurries also falls into this category. Advanced flue gas desulfurization processes and combined SO_2/NO_x processes generally are geared toward new construction. Applicability for retrofitting needs to be determined on a site-specific basis.

HEAT ENGINES

Description

GAS TURBINE ENGINES

The gas turbine engine converts part of the energy of a hot gas stream to shaft horse power which can be used to generate electricity, pump liquids or gases, or drive vehicular or marine propulsion systems. Moreover, the excessive thermal energy can be used directly in industrial processing (cogeneration) or to generate additional electricity through a steam turbogenerator bottoming cycle (combined cycle).

Gas turbine power did not begin to penetrate the utility and industrial market to any significant extent until the mid-1960s. In 1966, installed capacity had reached only 2500 MW; by 1980, capacity had expanded to nearly 65,000 MW. Most of this growth occurred between 1965 and 1975.

The remarkable growth of gas turbine power in the 1960s was made possible by: (1) the development of a strong, progressive gas turbine manufacturing base in response to the rapid acceptance of gas turbine power by commercial airlines following World War II, and (2) an increasing recognition of the efficiency, cost, lead-time, and modularity advantages of gas turbine power in certain industrial and utility power applications. The equally remarkable reversal of gas turbine growth in the 1970s resulted from global price pressures. Gas turbine fuel sold for about $2.00 per million Btu in 1970; by 1975 prices had risen to $3.53 and by 1982 to $8.50. While current fuel costs are lower, the trend of costs for natural gas and petroleum-based fuels is upward. A less expensive alternative clean fuel is needed. Cost and/or availability limits consideration of natural gas to a few favorable geographic locations. Coal- or shale-derived liquids are limited by environmental and economic factors. It is clear, however, that coal, as the cheapest and most abundant raw material, offers significant potential as a source of a less expensive alternative fuel. To utilize this resource, clean coal technologies are required to produce coal-fueled gas turbine systems at commercially competitive prices while meeting environmental standards.

DIESEL ENGINES

The diesel is a high-compression, sparkless, internal combustion engine. Unlike the spark-ignition, gasoline-fired, internal combustion engine, the diesel burns lower cost fuel oils, e.g., No. 2 diesel fuel. The diesel will also accept, with suitable engine design modifications, heavier petroleum distillates, natural or medium-Btu gas, or liquid fuels derived from coal or oil shale providing they are thoroughly de-ashed and free of deleterious impurities.

The diesel offers major benefits in efficiency, load-following capability, compactness, and capital cost. These intrinsic advantages have earned distillate-fired diesel power a dominant position in critical U.S. and foreign transport, utility, and industrial applications. The development of a coal-fueled diesel could provide economic stability to the users and manufacturers of these engines.

Environmental Characteristics

GAS TURBINE ENGINES

Coal-fired gas turbine power systems are expected to meet present environmental emissions regulations for particulates, NO_x, and SO_2. DOE studies indicate that exhaust gas cleanup systems, when applied to gas turbines, are uneconomical due to the high air flow. Therefore, control of emissions must be accomplished within the turbine by means of staged combustion to control NO_x, by gas stream SO_2 removal devices, and by high temperature filtering devices to control particulates.

DIESEL ENGINES

Presently there are no emissions regulations pertaining to diesel engines. Because there is no opportunity to clean the working fluid within the engine, cleanup must be accomplished in the supplied fuel or in the engine exhaust, perhaps using a combination of highly beneficiated fuel and exhaust cleanup devices.

Status of Development and Work in Progress

GAS TURBINE ENGINES

The direct firing of coal in gas turbines was attempted in the 1950s and 1960s, mainly in the United States and Australia. Inability to solve the serious erosion, corrosion, and ash deposition problems that were encountered forced the abandonment of these efforts. The gas turbine is extremely sensitive to certain fuel impurities, particularly compounds of sodium, potassium, calcium, sulfur, vanadium, lead, and other elements. Fuel specifications for high-efficiency, modern turbines operating at temperatures in the 1900 °F range restrict these impurities to a few parts per million (ppm) and, in the case of the most deleterious impurities (e.g., sodium), to less than 1 ppm. If these limits are exceeded, the system must be derated by reducing the operating temperature and periodically cleaning the turbine blades and vanes of accumulated deposits from impurities.

Refined coal liquids can be produced that meet turbine standards, but projected costs and market uncertainties have thus far deterred commercial development. The current DOE program focuses on potentially lower cost coal-based fuel forms, i.e., minimally cleaned fuel gas and fine particulate coal in either dry powder or slurry form. In addition to clean coal-based fuels, the program is investigating post-combustion cleanup techniques that could allow the burning of a poorer quality fuel while still protecting the power turbine.

Several advanced clean coal technologies are being explored in the current program. First, improved coal gasification and gas cleaning processes have been developed that are capable of delivering the fuel gas quality required for high performance turbine operation. The 100-MW Cool Water combined-cycle plant in California exemplifies several such advanced technologies. Current DOE work is directed toward lower cost systems based on more efficient gasification and gas cleaning methods. Other advanced clean coal technologies being applied in the DOE program relate to grinding, cleaning, and slurrying very fine coal particles. New fuel forms based on these technologies are being developed in parallel with gas turbine designs required to accommodate them.

Progress in both the gaseous fuel and the fine particulate coal approaches has been highly encouraging. Component development work has been initiated by major gas turbine engine manufacturers under a DOE contract in connection with the fuel gas approach. The fine particulate coal fuel concept research is concentrated on fuel quality, combustor design interactions, and their effects on turbine durability.

DIESEL ENGINES

The principal problems with using lower quality, petroleum-based fuels in diesel engines relate to combustion deficiencies, corrosion, and wear. The combustion problem is associated with low cetane ratings (a general measure of the compatibility of diesel fuel combustion characteristics with engine operating requirements). The corrosion and wear problems are mainly associated with fuel-bound impurities and ash-forming minerals. In diesel fuel terminology, "lower quality" generally refers to residual oils or heavier distillates. When specially treated to remove harmful impurities and improve combustion characteristics, these fuels may be used instead of the conventional "clean" No. 2 diesel fuel. Research efforts both in private and government laboratories in the United States and Europe are taking this approach. European operators are using residual oil in large, slow-speed engines that are inherently more tolerant of lower quality fuels than the medium and high-speed engines that predominate in the United States. Railroads and other private sector and Federal programs (e.g., the Department of Transportation) are attempting to modify engine design and operating factors which would permit the use of specifically defined, lower cost, residual and blended fuels.

Because of long-range cost and supply uncertainties as associated with these synfuel and petroleum-based alternatives, the DOE program is also looking at new coal-derived fuel forms. Coal was first evaluated as a fuel in diesel engines in Germany in the early 1940s. Coal dust was tried in a slow speed engine but excessive cylinder wear discouraged continuation. The coal used in these early tests did not have the benefits of present day "clean coal" technologies. The current DOE program is based on several of these advanced technologies (i.e., coal benefication, fine grinding, special fuels formulation, coal gasification, and hot gas cleaning). The coal-fired diesel work has progressed to preliminary test evaluation along with bench-scale research on combustion characteristics, fuel injection, and component wear. So far, this work has considered highly beneficiated, fine particulate coal-water slurries. Test evaluations of a coal slurry fuel have been made in slow- and medium-speed test engines; the fuel burned and successfully powered the engines. Engine wear effects have not yet been evaluated. In addition, laboratory bench tests have been conducted to establish fundamental data relevant to engine design features required to utilize these fuels. Major U.S. diesel engine locomotive manufacturers have been consulted in the initial engineering phases of a program aimed towards definition of realistic fuel (both slurry and gaseous) and design requirements for the application of coal fuels to future diesel power systems.

PROJECTS IN PROGRESS

The DOE report, *America's Clean Coal Commitment*, of February 1987, identified a nationwide inventory of clean coal technology development and demonstration projects receiving significant public and/or private sector funding in the 1986-1992 time interval. No specific projects in the heat engines technology category were identified. However, the integrated coal gasification combined-cycle projects listed in the section on surface coal gasification support gas and/or steam turbine development.

Relationship between the R&D Program and CCT-I

DOE's Heat Engines Program is now primarily investigating the direct combustion of coal in gas turbines and in diesel engines; there are no CCT-I projects that involve this technology. However, the following two CCT-I projects relate otherwise to heat engines:

1. M.W. Kellogg Company--Fluidized-bed gasification with hot gas cleanup and integrated combined-cycle.

2. Consolidation Coal Company/Foster Wheeler Power Systems, Inc.--Integrated coal gasification with combined-cycle and hot gas cleanup.

While neither of these projects are intended specifically to demonstrate heat engines, the technology supports gas and/or steam turbine development. Both projects involve an integrated gasification combined-cycle (IGCC) system to demonstrate coal gasification with hot gas cleanup. A DOE project completed in 1985 demonstrated that a hot gas particulate removal system could provide a satisfactory low-Btu fuel gas to a gas turbine test rig. The deposition rate was considered to be low enough to ensure an acceptable operating period between cleanups. The additional cleanup component provided in the M.W. Kellogg and Consolidation Coal projects is a zinc-ferrite sulfur removal system which has no significant effect on the operation of the gas turbine. These two clean coal projects also will demonstrate the new hot gas cleanup technologies.

Applicability of the Technology to Retrofitting, Repowering, or Modernizing Existing Facilities

GAS TURBINE ENGINES

The extensive use of gas turbines in the utility market since the 1960s has resulted in several repowering applications. Repowering can be achieved by utilizing the heat in the exhaust of a gas turbine to generate steam, which in turn is used to run an existing steam turbine power plant; the original boilers are scrapped. The resulting configuration is a combined-cycle power plant. Adding the ability to burn a coal fuel makes the gas turbine even more attractive for repowering projects. The coal-burning gas turbine is, therefore, an excellent choice for repowering applications. Details, of course, depend on the specific repowering project.

As far as retrofitting or modernizing applications are concerned, it is entirely possible that, if the proper fuels are developed, an existing oil- or gas-fired gas turbine could be refitted to burn a highly beneficiated coal-water mixture. However, economics and fuel availability will be more significant factors than technology availability in a decision to make such a conversion.

DIESEL ENGINES

There is no likely application of a coal-burning diesel engine for retrofitting, repowering, or modernizing existing facilities. Cost considerations are such that coal-fueled diesel engines are economic as originally installed equipment, but not as modifications to prior installations. However, the use of coal-derived liquids (e.g., from mild gasification) may be a possible alternative to diesel fuel.

COAL LIQUEFACTION

Description

Coal liquefaction produces useful liquid fuels from all domestic coal resources (bituminous, subbituminous, and lignite). There are two primary methods of coal liquefaction: (1) indirect liquefaction (coal gasification followed by conversion to liquid fuels) and (2) direct liquefaction (conversion of the complex organic solid structures in coal directly into liquid fuels). These methods are discussed below.

INDIRECT LIQUEFACTION

Indirect liquefaction involves the gasification of coal to produce a raw synthesis gas, water-gas shift reaction to adjust the H_2:CO ratio of the synthesis gas, gas cleanup, and the liquid synthesis process itself. A major challenge in process conception and design is to couple these stages in the most economic, thermally efficient manner.

Coal-derived synthesis gas is produced at high thermal efficiency by modern gasifiers that use the minimum amounts of oxygen and steam feed. The gas so produced has a low H_2:CO ratio, i.e., in the range of 0.6 to 0.7. Because of the significant contribution of gasification to the total cost of indirect liquefaction, the ideal synthesis reaction would accept such feed ratios directly. Unfortunately, neither traditional Fischer-Tropsch processes nor methanol-forming processes will accept a low H_2:CO feed ratio. In either case, the water-gas shift reaction would first have to be applied to increase the H_2:CO ratio to 2 or higher. However, this leads to a loss in thermal efficiency.

The best known approach to indirect liquefaction is the Fischer-Tropsch technology, which is the basis for the largest commercial liquefaction facilities in the world. These facilities are operated in South Africa by the South African Coal, Oil and Gas Co., Ltd. (SASOL). The new SASOL II and III plants employ dry ash Lurgi Mark IV gasifiers of German design and fast fluid (entrained recirculating) bed Synthol Fischer-Tropsch synthesis reactors developed by SASOL based on technology originally provided by the U.S. firm, M.W. Kellogg. This combination of steps at SASOL is capable of delivering clean fuels including a large percentage of gas and petrochemicals with an efficiency approaching 60 percent.

Since 1983, the Tennessee Eastman Company has operated the only coal-to-methanol plant in the United States. A single Texaco gasifier (plus one back-up) processes 900 tons per day of coal to produce methanol as an intermediate in the production of methyl acetate and acetic anhydride. In New Zealand, gasoline is commercially produced from synthesis gas by the Mobil MTG process.

DIRECT LIQUEFACTION

In direct liquefaction, ground coal is slurried with a recirculated process-derived oil and reacted under heat and hydrogen pressure. The liquefaction reactions can be carried out in the presence or absence of catalysts and in a single reactor or in multiple reactor stages. At some point in the process sequence, following coal dissolution, mineral matter and unconverted coal solids must be removed from the process; solids removal technology is an important aspect of liquefaction processing. Liquid products and recycle solvent are recovered by distillation. Middle distillate and heavier liquid products can be used directly as turbine fuel and/or fuel oil. Material that boils in the same temperature range as petroleum-derived naphtha has been shown to be an excellent feedstock for refining to yield high octane gasoline. Middle distillate and heavier liquid products also can be upgraded, using petroleum refining technology, to a broad spectrum of high quality, specification liquid fuel products.

Four direct liquefaction processes have been tested through the pilot-plant stage: (1) Exxon Donor Solvent, (2) H-Coal, (3) Solvent Refined Coal-I (SRC-I), and (4) SRC-II. Each was developed in the mid- to late-1970s and uses a single reactor stage. These processes are described below.

1. Exxon Donor Solvent--The Exxon Donor Solvent process liquefies coal in a hydrogen-donor solvent produced in a separate catalytic hydrogenation reactor. Pulverized coal slurried in recycled donor solvent is mixed with hot hydrogen and passed through the main (liquefaction) reactor. Recycled process solvent, circulating first through the catalyst vessel, picks up hydrogen atoms and then passes into the liquefaction reactor and "donates" the hydrogen to the dissolved coal--hence the name "donor solvent."

   The products leaving the main reactor are separated. Hydrogen for reuse is recovered from the gas through cryogenic separation. An atmospheric distillation step yields a slate of light, middle, heavy distillate, and solid residue fractions. A portion of the middle distillate is used to produce the donor solvent. The residue proceeds to vacuum fractionation, which yields additional distillate, spent solvent range distillate, and vacuum residue. This residue, which contains unconverted coal and ash, may be gasified to produce hydrogen for the liquefaction.

2. H-Coal Process--The H-Coal process (developed by Hydrocarbon Research, Inc.) is a direct catalytic hydroliquefaction process for converting coal into hydrocarbon liquid fuels. Depending on the operating scheme, the product may be all distillate (syncrude mode) or high-boiling-point boiler fuel including deashed residue (fuel oil mode).

   The properly sized and dried coal feed is mixed with recycled slurry and process-derived solvent (normally a part of the heavy distillate oil product). The coal/oil slurry, along with part of the recycled hydrogen, is preheated to initiate the coal dissolution, and then introduced to the bottom of an ebulated-catalyst bed reactor. The remaining hydrogen feed is preheated and introduced to the bottom of the reactor.

   The gas, liquid, and coal/oil slurry are separated and further processed to meet the specifications of the process recycle streams as well as hydrotreated and stabilized to meet commercial specifications. The coal/oil slurry is partially concentrated in a hydroclone system. The hydroclone underflow and portions of the heavy distillate oil are used to slurry the fresh coal feed. Further oil recovery and solids concentration from the hydroclone underflow are achieved through vacuum distillation of this stream in the syncrude mode and through solvent precipitation and critical flashing in the fuel oil mode. The vacuum bottoms, containing mostly unreacted coal and ash, are gasified to produce the hydrogen for the process.

3. Solvent Refined Coal--The Solvent Refined Coal process is a noncatalytic (thermal) process for converting high-sulfur, high-ash coals to nearly ash-free, low-sulfur fuel. The process has two different modes of operations: SRC-I which yields a solid fuel, and SRC-II which yields primarily distillate liquid fuels.

   o In SRC-I, properly sized dried coal is slurried with a process-derived solvent. The slurry, mixed with hydrogen, is preheated and sent to the reactor. The reactor effluent is sent to the vapor-liquid separation stage. Hydrogen (for recycle), fuel gas, and eventually sulfur are recovered from the primary gaseous stream. Process solvent and other liquid components are removed from the separator slurry, and the remaining slurry is sent to a deashing step in which it is separated into a molten carbonaceous product stream and a solid residue stream. The residue stream is gasified to produce make-up hydrogen.

   o SRC-II is a modification of SRC-I and produces primarily liquid fuels instead of solids. SRC-II uses proportionally more hydrogen than the SRC-I process and also uses a residue containing slurry recycle (ash in the slurry acts as a catalyst) to achieve higher conversion of coal to liquid products. A portion of the ash slurry is removed from the recycle stream and fractionated to produce distillates. The heavy residue is gasified to produce make-up hydrogen.

Environmental Characteristics

INDIRECT LIQUEFACTION

The environmental characteristics of indirect liquefaction processes are essentially the same as the environmental characteristics of surface coal gasification technologies. The environmental benefit of the gasification technologies is that the gaseous sulfur and nitrogen compounds can be removed before combustion or chemical manufacture using either wet scrubbing or high-temperature absorption/adsorption processes.

Hydrogen sulfide removal can be achieved through chemical or physical absorption after gas cooling or by adsorption on metal oxides at high temperature (1000 °F to 1200 °F). These processes can remove more than 99 percent of the gaseous sulfur compounds before combustion of the gases. The sulfur species absorbed in chemical solutions (cold cleanup) can be recovered as elemental sulfur or converted to sulfuric acid. From the metal-oxide adsorption process (hot cleanup), the sulfur compounds can be recovered as sulfur or converted to sulfuric acid or solid sulfates (such as calcium sulfate), which ultimately can be disposed of in a landfill.

In addition, sulfur compounds can be captured within the gasifier through the addition of limestone (or dolomite). Using this method, capture levels of approximately 90 percent are possible, and further capture ("polishing") can be achieved by treating the fuel gas with a metal oxide adsorption process to exceed 99 percent of total sulfur removal.

Nitrogen compounds (principally ammonia) are generated in the gasification process and, depending on the gasifier operation temperature, are contained in varying amounts in the synthesis gas. The highest ammonia levels are produced in the lowest temperature reactor, i.e., fixed-bed gasifiers; lesser amounts are produced in fluid-bed reactors; and the lowest amount in entrained reactors (which have the highest operating temperature). The nitrogen compounds are easily removed in cold cleanup systems by dissolution in water and subsequently recovered as salable ammonia. After cold cleanup, fuel gas contains only traces of ammonia, and upon combustion, the NO_x emissions are far below current NSPS. With hot gas cleanup systems, the ammonia passes through into the fuel gas and NO_x emissions must be controlled by combustion modifications or external processes. In either treatment, the fuel gas can meet current NSPS.

The principal solid waste from the gasifier is coal ash, which can be disposed of in the same manner as coal-fired boiler ash. When limestone is injected into the gasifier, the solids will contain calcium sulfides, and it will be necessary to oxidize these solids to convert sulfides to sulfates, which are inert and can be disposed of in landfill.

Catalytic synthesis of liquid products such as methanol or Fischer-Tropsch products creates no significant emissions. When methanol is co-produced with electricity, a portion of the synthesis gas is converted and the methanol condensed. The remaining unreacted fuel gas (mostly CO) is burned in a turbine with a steam bottoming cycle. Since cold cleanup systems must be used to eliminate essentially all sulfur, nitrogen, and particulates (which will poison the synthesis catalyst), the fuel gas being fired to the combustor is also free of these compounds. Thus, the exhaust gases from the turbine/boiler will be low in NO_x (below NSPS) and SO_2 and will be free of particulates. Stored methanol can be used in peaking or transportation fuel applications. Methanol combustion in turbines has been used by utilities, and the process is very low in NO_x emissions and is free of sulfur and ash. Fischer-Tropsch products can substitute for conventional refinery-produced diesel and gasoline fuels with potentially very low SO_2 and NO_x emissions.

DIRECT LIQUEFACTION

Direct liquefaction technologies generally involve hydrocracking of the coal molecules, either thermally, or catalytically, to produce smaller molecules. These smaller molecules can then be upgraded to specification fuels where essentially all heteroatoms (sulfur, nitrogen, and oxygen) are removed by reaction with hydrogen.

Emissions from the plants can be reduced effectively through proper design. Sulfur is converted to salable elemental sulfur. Oxygen in the coal is generally reacted with hydrogen to form water. Nitrogen is hydrotreated to form salable ammonia. Mineral matter ends up in the vacuum bottoms product which can be used to produce hydrogen in a gasifier or burned in a boiler.

In either case, the mineral matter is converted to a refractory-like slag or to fly ash products that are expected to be nonhazardous. Waste water treatment technologies, such as those used in refineries or in coal gasification plants, can be used to eliminate nearly all phenols, ammonia, and other compounds. The plants can be designed to reuse waste water (zero discharge) with blowdowns evaporated to small quantities of solid salt products that can be disposed of at approved sites.

Coal liquefaction technologies provide liquid fuels from coal for a wide variety of market applications. Both direct and indirect liquefaction can be used to produce finished fuels that are virtually indistinguishable from petroleum products.

Status of Development and Work in Progress

INDIRECT LIQUEFACTION

Primary objectives of the DOE Indirect Liquefaction Program are to (1) achieve more selective and economic yields of liquid fuels and (2) achieve better utilization of coal-derived gas feedstock. To accomplish these objectives, the program supports research that identifies and investigates processes based on:

1. New catalysts or biocatalysts able to utilize low hydrogen/carbon monoxide syngas, thereby taking advantage of the new, efficient gasifiers now under development in the United States

2. New or modified catalysts with the selectivity to produce desirable liquids either in a single stage or via chemical intermediates in a two-stage synthesis process

3. Thermally efficient reactors with improved temperature control and heat recovery compared with reactors currently available for indirect liquefaction reactions.

Successful research will permit a significant reduction in the cost of each of the following major process areas downstream of the coal gasification step:

1. Cleanup and shift of the new syngas to provide required feedstock for the synthesis step

2. Recycle of gas to the reactor to maintain proper gas composition and reactor temperature

3. Conversion of syngas feedstock to desirable liquids

4. Separation and refining of produced liquids to marketable products.

The broad-based research program now in place includes laboratory-scale research to investigate the mechanisms of known catalyst components and new catalyst systems with higher selectivity, stability, resistance to poisoning, and overall productivity. Projects also are under way at the laboratory scale to develop data required to realize the technical and economic potential of performing the synthesis reaction in a liquid phase. Multiphase reactors are used in this research and in hydrodynamics studies of advanced reactor designs.

Two process concepts have been scaled up from laboratory scale for further development and evaluation in proof-of-concept facilities. The larger project was an international one with a pilot plant located in West Germany. This project has been successfully completed. The plant used an advanced fluid-bed reactor system to convert, very efficiently, 100 barrels per day of methanol to high octane gasoline. A second mode of operation to produce light olefins for conversion to diesel fuel and/or gasoline also has been successfully accomplished.

The second proof-of-concept development effort involves the production of methanol from a simulated coal-derived synthesis gas. The facility, located at La Porte, Texas, produces about 35 barrels per day of methanol using a liquid phase reactor system, and has operated successfully in a single pass mode utilizing CO-rich synthesis gas.

DIRECT LIQUEFACTION

The technical viability of direct coal liquefaction has been demonstrated. Processes capable of producing the entire slate of liquid fuels currently derived from petroleum crude are available. However, those processes that are ready for commercialization are currently not economically competitive with petroleum-derived fuels. Therefore, new process concepts or substantial improvements to existing approaches are necessary before economic viability can be achieved.

DOE's Coal Liquefaction Program has identified the major improvements needed for advanced processes to become more economically competitive. These targets are:

1. Achieve 10-15 percent higher yields than those achieved by already demonstrated processes

2. Realize up to 30 percent savings in capital and operating costs through improvements in ease of operation and reductions in process severity and complexity

3. Reduce heteroatom content by 40-50 percent and/or increase the hydrogen content in the liquid product by 10 percent compared to already demonstrated processes

4. Implement process modifications or new process concepts capable of producing liquid products that are comparable in bioactivity to their petroleum analogs.

Staged liquefaction is an advanced process that provides improved, lower cost technology. Several processes based on this approach have completed bench-scale development and have been or are being evaluated at the Advanced Coal Liquefaction R&D Facility in Wilsonville, Alabama. More advanced, staged-liquefaction technology options are being developed at the bench scale.

Another process concept under evaluation is coal-oil coprocessing. In this concept, coal is slurried in residual fuel oil rather than recycle solvent, and both coal and petroleum residuals are converted to high quality fuels in subsequent processing. This concept offers the potential for significant cost reduction by eliminating or reducing internal recycle oil requirements. As a result, there is a much higher net throughput of product per unit of plant capital investment. It also offers the potential for accelerating the introduction of coal-derived liquid fuels into the marketplace by utilizing, to a substantial degree, existing petroleum refining facilities and technology. This will allow the introduction of coal-based liquid fuel in an evolutionary manner and delay the requirement for new, capital intensive, liquefaction facilities. This work is being conducted at the bench scale.

PROJECTS IN PROGRESS

The DOE report, *America's Clean Coal Commitment*, identified a nationwide inventory of clean coal technology development and demonstration projects receiving significant public and/or private sector funding in the 1986-1992 time interval. One project was identified in the coal liquefaction technology category; a project description is provided in Appendix B of the aforementioned report. The project is listed below.

Project in Progress

No.	Project	Site
7	Ohio Ontario Clean Fuels Inc. Oil/Co-Processing Liquefaction	Warren, OH

Source: *America's Clean Coal Commitment* (DOE/FE-0083), U.S. Department of Energy, February 1987.

Relationship between the R&D Program and CCT-I

The Prototype Commercial Coal-Oil Coprocessing Project (Ohio Ontario Clean Fuels, Inc.) is one of the CCT-I projects. The data being generated in DOE's Coal Liquefaction Program can be used to evaluate the design of this project. In turn, operational data from the project can serve to focus the R&D effort to overcome problems that hinder advancement of the state-of-the-art of the technology and its optimization for commercial application.

Applicability of the Technology to Retrofitting, Repowering, or Modernizing Existing Facilities

Coprocessing technology can be used to retrofit existing petroleum refineries, and this is the main reason why the technology is being developed. Coal and ash handling facilities would be retrofitted to existing heavy oil refinery processing equipment. At an appropriate crude-oil-to-coal price differential, this would allow a refiner to reduce the cost of feedstocks while increasing the production of high-quality liquid fuels from scarce and/or expensive crude oil supplies.

Indirect liquefaction could be used to retrofit facilities having existing coal gasification technology or to retrofit and modernize existing non-coal-derived synthesis gas facilities. Liquefaction reactors would be added downstream of the synthesis gas cleanup train, providing a reactively low-cost conversion of coal-derived or other gas to high-quality liquid fuels.

Direct liquefaction is suitable for retrofitting and modernizing existing refinery or chemical processing facilities to utilize coal feedstocks. The existence of ancillary facilities and utilities at these sites and the elimination or reduction of complex siting and environmental requirements adds to the attractiveness of this approach. Products for direct liquefaction, indirect liquefaction, and coprocessing all can be used for retrofitting/refueling a coal-, gas-, or oil-fired boiler in repowering applications.

SURFACE COAL GASIFICATION

Description

Coal gasification involves the conversion of the solid fuel, coal, and other carbonaceous materials into gas and liquid fuels through chemical reactions usually involving steam and oxygen or air. The gasification process provides a convenient mechanism for the removal of sulfur and ash from coal while producing the product gas, which is generally a mixture of hydrogen, carbon monoxide, methane, steam, carbon dioxide, nitrogen, and other minor impurities. The conversion of coal to product gas is accomplished by the introduction of an oxidizing agent (air and/or oxygen and/or steam) into a reactor vessel where this agent can come into intimate contact with a suitably prepared coal feedstock in a controlled reducing atmosphere. The composition of the product gas is greatly influenced by parameters such as temperature, pressure, and type of coal.

Once generated, the raw product gas leaving the reactor is processed through a number of sequential gas treatment steps determined by the end use for the gas and environmental requirements. These gas treatment steps generally can be classified as low temperature or high temperature systems. Low temperature (i.e., 100 °F to 300 °F) systems most often are state-of-the-art technology representing relatively problem-free operation with high availability. On the other hand, high temperature (i.e., 800 °F to 1200 °F) technology is just reaching the demonstration stage and represents possible improvements in efficiency in future applications of some gasification technologies. This series of sequential steps that constitute a coal gasification process can be used to convert all types of coal into a wide range of products, including clean low- and medium-Btu gas suitable for industrial processes and power generation or a synthesis gas suitable for subsequent conversion into products that range from chemical feedstocks to high-grade transportation fuels.

Gasification of coal with air produces a low-Btu gas with heating values in the range of 125-150 Btu per standard cubic foot (scf). Gasification of coal with oxygen creates a medium-Btu gas with heating values in the range of 250-350 Btu per scf. Both can be used directly as fuel. Medium-Btu gas can be converted to hydrogen for ammonia synthesis or upgraded to a substitute natural gas with heating values of 950-1000 Btu per scf or used as a feedstock for chemical synthesis reactions yielding products such as methanol and ammonia.

Despite the variety in specific gasification processes, all are fundamentally similar in that they involve conversion (devolitalization and gasification) of coal to produce a mixture of hydrogen and carbon monoxide, called synthesis gas, for use as fuel or for further processing in an environmentally acceptable manner. Major energy applications in which coal gasification technology can be used include:

1. Production of electric power using integrated coal gasification combined-cycle systems

2. Production of (low- or medium-Btu) fuel gas for industrial processes

3. Production of synthesis gas for use as a chemical feedstock, manufacture of hydrogen, conversion to substitute natural gas, and as a feedstock for indirect coal liquefaction processes

4. Production of hydrogen for direct liquefaction

5. Disposal of solid wastes containing carbonaceous material

6. Manufacture of coproducts such as char, fuel gas, and distillate liquids for use as fuels in advanced energy conversion machines.

Environmental Characteristics

Surface coal gasification technologies convert coal (in the presence of an oxidant--air or oxygen--and steam) to a fuel gas composed primarily of carbon monoxide and hydrogen. The fuel gas is burned in boilers to raise steam to generate electricity indirectly or in gas turbine combustors to generate electricity directly. If desired, the carbon monoxide/hydrogen mixture can be processed further to make ammonia or liquids such as methanol. In the production of the fuel gas from coal, the ash is discharged as dry solids, the fuel-bound nitrogen is converted to ammonia, and fuel-bound sulfur is converted to hydrogen sulfide and other organic sulfides such as carbonyl sulfide and mercaptans. The benefit of the gasification technologies is that the gaseous sulfur and nitrogen compounds can be removed economically and effectively before combustion.

Hydrogen sulfide removal can be achieved through chemical or physical absorption after gas cooling or by adsorption on metal oxides or their derivatives at high temperatures (1000 °F to 1200 °F). These processes can remove more than 99 percent of the gaseous sulfur compounds before combustion of the gases. The sulfur species absorbed in chemical solutions (cold cleanup) can be recovered as elemental sulfur or converted to sulfuric acid. From the high temperature processes (hot gas cleanup), the sulfur compounds can be recovered as sulfur (at great expense) or converted to sulfuric acid or solid sulfates (such as calcium sulfate), which ultimately can be disposed of in a landfill.

In addition, sulfur compounds may be captured within lower temperature gasifier technologies through the addition of limestone or dolomite. Capture levels of approximately 90 percent may be possible using this method, and further capture ("polishing") to exceed 99 percent total sulfur removal might be achieved by treating the fuel gas with a metal oxide adsorption process.

Nitrogen compounds (principally ammonia) are generated during the gasification process and, depending on the gasifier operating temperature, are contained in varying amounts in synthesis gas. The highest ammonia levels are produced in the lowest temperature reactor (e.g., fixed-bed gasifiers); lesser amounts are produced in fluid-bed reactors; and the lowest amount in entrained-bed reactors (which have the highest operating temperature). The ammonia compounds are easily removed in cold cleanup systems by dissolution in waste liquor streams and are subsequently recovered as salable ammonia for fertilizer applications. After cold gas cleanup, fuel gas contains only traces of ammonia, so that upon combustion the NO_x emission is far below current NSPS. With hot gas cleanup systems, the ammonia passes through into the fuel gas. Thus, NO_x emissions must be controlled by combustion modifications or external/internal NO_x removal processes when this fuel gas is combusted. In either treatment, the fuel gas can meet current NSPS.

When the fuel gas is burned in a gas turbine to produce electricity, the level of entrained particulate matter in the fuel gas must be controlled to a low level to protect the gas turbine and to meet current NSPS. The solids captured during gas cleanup are disposed of as solid wastes along with the primary ash from the gasifier. When the fuel gas is burned directly in a boiler, the suspended solids in the boiler discharge gas are controlled by conventional means. In this case, however, the level of input solids will be significantly below the level normally produced from direct coal combustion and removal will be to levels below current NSPS.

The solid waste from the gasifier will be coal ash, which can be disposed of in the same manner as coal-fired boiler ash. In fact, the solid waste from a high temperature gasification process is an inert material with many byproduct uses. When limestone is injected into the gasifier, the solids will contain calcium sulfides. It will be necessary to oxidize these solids to convert sulfides to sulfates which are inert and can be disposed of in a landfill.

Some lower temperature gasification processes produce condensable hydrocarbons during early stages of the gasification reactions. In these gasification processes, using a cold-water cleanup system will require treatment of the wastewater to remove organic compounds before discharge. However, in systems employing hot gas cleanup processes, the gases are maintained at a high temperature (greater than 1000 °F) and burned directly at this temperature. The tars and oils produced are maintained in the vapor phase and decomposed during combustion.

Status of Development and Work in Progress

Gasification processes of all types are in operation in the United States and worldwide. Considerable research and development work is now in progress to produce advanced gasification systems that generate minimal environmental emissions and that are economically viable.

Even though the decline of oil prices in the 1980s has prompted a reassessment of priorities for the commercialization of processes, numerous demonstration studies have been completed or are under way, and a commercial plant for production of substitute natural gas and a plant for production of acetic anhydride have been put on-stream, as well as utility and industrial power generation projects. In several cases where a specific application of coal gasification technology could be identified, industry has assumed the responsibility for continuing the development of advanced gasifiers from the proof-of-concept stage into the demonstration phase. In other cases, the government has provided some form of support to stimulate further development. Some of these demonstration projects include:

1. Great Plains Gasification Project--Great Plains is a commercial facility in North Dakota using Lurgi gasifiers to produce 125 million Btu per day of substitute natural gas for commercial pipeline distribution. DOE provided a loan guarantee to assist industry in this venture. After successfully starting up and operating the facility, the partners in Great Plains Gasification Associates notified the government on August 1, 1985, that they were terminating their participation in the project and the partnership, and on that date defaulted on the Federal loan it received to build the plant. DOE paid off the approximately $1.6-billion of debt then outstanding, foreclosed on the collateral, and, under Federal ownership, operated the facility until its sale to the Dakota Gasification Company on October 7, 1988.

2. Cool Water Coal Gasification Project--The Cool Water plant consumes 1000 tons per day of coal in a Texaco gasifier to produce synthesis gas for use in an integrated coal gasification combined-cycle system. The U.S. Synthetic Fuels Corporation provided price guarantees to this project. This plant is being operated in Daggett, California. The project demonstrated two versions of the technology: one for power generation and one for chemical synthesis gas generation.

3. British Gas Corporation/Lurgi Slagging Gasifier--The British Gas Corporation has constructed a commercial size gasifier at its Westfield Test Facility. The gasifier is being operated to confirm scale-up parameters and to define operating parameters for different coals.

4. Tennessee Eastman/Chemicals from Coal--A Texaco gasifier (900 tons per day) has been constructed at Kingsport, Tennessee, as part of a commercial plant. Demonstration of the gasifier and a process for the production of acetic anhydride from coal will continue.

5. TVA Ammonia from Coal--A small Texaco gasifier (225 tons per day) has been used in a development project to produce ammonia for fertilizer manufacture. This Tennessee Valley Authority project is located near Muscle Shoals, Alabama.

6. High-Pressure High-Temperature Winkler Gasifier--Rheinbraun, Inc., of West Germany has constructed and is operating a demonstration-size (55 tons per hour) high-temperature, high-pressure Winkler gasifier as the first phase of a program to develop this gasifier and a process for producing methanol from coal.

7. Dow Syngas Project--An entrained-flow, coal-slurry fed plant (2400 tons per day) is being operated at Plaquemine, Louisiana. This project contains the world's largest gasification train (2400-3000 tons of coal per day). The process consists of a two-stage reactor concept to produce power, steam, and byproduct sulfur. This project is receiving price supports under a U.S. Synthetic Fuels Corporation agreement now monitored by the U.S. Treasury.

8. Shell Coal Gasification Process--An entrained-flow gasification plant (250-400 tons per day) designed to operate at high pressure and temperature to produce coal gas for power generation is operating at Deer Park, Texas. This plant is being developed by Shell Development Company.

In addition to these activities, DOE has supported the development of other advanced gasifier systems through the process-development-unit and pilot stages. Examples of these are the Catalytic Coal Gasification reactor; the fluidized-bed agglomerating ash gasifiers (e.g., U-Gas and KRW); and the CO_2 Acceptor and Hygas reactor systems.

These development activities have provided a variety of gasifiers and processes that offer a full range of operational as well as feedstock capabilities. Moreover, they have demonstrated the ability to convert coal into a variety of gaseous and liquid fuels as well as chemical feedstocks. Subsequent implementation of gasification technology will depend upon future energy demands and the availability of natural gas and oil to meet these demands as well as the environmental requirements of existing and future facilities.

The aforementioned projects have defined the economic and environmental performance of those gasification technologies being demonstrated. Much of the information needed to perform a commercial evaluation is being made available.

PROJECTS IN PROGRESS

The DOE report of February 1987, *America's Clean Coal Commitment*, identified a nationwide inventory of clean coal technology development and demonstration projects receiving significant public or private sector funding in the 1986-1992 time interval. There are eight projects in the surface coal gasification technology category; descriptions are provided in Appendix B of the aforementioned report. The projects are listed below.

Projects in Progress

No.	Project	Site
8	M.W. Kellogg Company/Fluidized-Bed Gasification with Hot Gas Cleanup Integrated Combined Cycle	Cairnbrook, PA
11	Allis Chalmers/KILnGAS Coal Gasification Project (co-funded with EPRI and the State of Illinois)	Wood River, IL
12	Dow Chemical Co./Dow Syngas Coal Gasification Combined Cycle	Plaquemine, LA
13	Cool Water Gasification Combined Cycle (construction privately financed)	Daggett, CA
28	Shell Oil Coal Gasification Demonstration Plant	Deer Park Complex Houston, TX
29	New Jersey Energy Associates/140-MW Cogeneration Plant using Coal-Derived Gas	Sayerville, NJ
30	Synfuels Genesis International & Dravo Corp./ 37-MW Coal-Fired Cogeneration Plant	Colstrip, MT

Source: *America's Clean Coal Commitment* (DOE/FE-0083), U.S. Department of Energy, February 1987.

Relationship between the R&D Program and CCT-I

DOE's Surface Coal Gasification Program has funded research and development of several of the technologies addressed by the CCT Program. A technology that has been under development for several years is being used in a CCT-I project. This is M.W. Kellogg's integrated combined-cycle power plant using the KRW ash agglomerating fluidized-bed gasification process with hot gas cleanup.

Other technologies have been developed under DOE's research and development program funding including the Allis-Chalmers KILnGAS commercial module. DOE is funding activities at Texaco's Montebello facility which include design efforts that incorporate the Texaco gasifier with hot gas cleanup.

Applicability of the Technology to Retrofitting, Repowering, or Modernizing Existing Facilities

Gasification offers the opportunity for retrofitting, refueling and/or repowering existing coal-, gas- and oil-fired power plants with coal-derived fuel gas. Retrofitting/refueling applications would involve modifying an existing boiler to burn an alternative fuel (coal-derived fuel gas). Retrofitting an existing oil or natural gas boiler to use medium-Btu gas (300-500 Btu per scf) would require only minor modifications to the boiler and would result in no derating or loss of efficiency. Use of low-Btu gas (125-150 Btu per scf) would require considerably more modifications to the boiler and would probably result in derating and a lower efficiency. Repowering would involve the addition of one or more combustion turbines to an existing steam turbine power plant, which would result in increased capacity and reduced NO_x emissions.

Retrofitting or repowering provide for maximum use of existing equipment, thereby reducing capital costs. This would also extend the life of an existing plant, shorten construction schedules (compared to replacement with a new plant), and greatly reduce the time required for permit and regulatory approvals.

APPENDIX B
SUMMARIES OF PROPOSALS RECEIVED

LIST OF PROPOSALS RECEIVED, BY ASSIGNED PROPOSAL NUMBER

Proposal Number	Offeror	Abbreviated Project Title	Technology	Page Number
1.	Southern Company Services, Inc.	100 MW Demo. of Technol.	FST	5
2.	Southern Company Services, Inc.	500 MW Demo. of Adv. Wall-Fire	FGN	7
3.	Southern Company Services, Inc.	Demo. of SCR for Control of NO_x	FGN	9
4.	Southern Company Services, Inc.	Comb. Techn. for Reduct. NO_x	FGN	11
5.	Combustion Engineering, Inc.	Pulv. Coal NO_x Reduct. Reburn	FGN	13
6.	Combustion Engineering, Inc.	Post-Comb. Dry Sorbent Inject.	FSI	15
7.	Combustion Engineering, Inc.	C.E. Gasification Repowering	IGC	17
8.	Florida Power & Light Company	Florida Coal Gasification	IGC	19
9.	Combustion Engineering, Inc.	Commer. Demo. of WSA-SNOX Tech.	FGC	21
10.	Frontier Energy Corp.	Coal/Heavy Oil Hydrogenation	MSC	23
11.	Babcock & Wilcox Co.	5-MWe Demo. of SOX-NOX-ROX Box	FGC	25
12.	Pedco Incorporated	Ind. Demo. Pedco Rotary Cascad.	AFI	27
13.	Western Energy Company	Adv. Coal Conversion Process	FUP	29
14.	Independence, City of, Missouri	Repower Blue Valley Power Plant	AFU	31
15.	Calderon Energy Co.	Repower. via Novel IGCC Proc.	IGC	33
16.	Southwestern Public Service Co.	Circ. Fluid-Bed Repowering	AFU	35
17.	Passamoquoddy Tribe	Passamaquoddy ICCT Prog. Appli.	IND	37
18.	American Electric Power Serv. Co.	PFBC Repowering Project	PFB	39
19.	Bethlehem Steel Corporation	Coke Oven Gas Cleaning System.	IND	41
20.	Babcock & Wilcox Co.	Demo. of Low-NO_x Cell Burner	FGN	43
21.	Babcock & Wilcox Co.	Coal Reburning for Cyclone Boil.	FGN	45
22.	Babcock & Wilcox Co.	Furnace Limestone Injection	FSI	47
23.	Cogentrix/Coastal Joint Venture	The Williamsburg Project.	ADC	49
24.	Bechtel National, Inc.	Confined Zone Dispersion FGD	FSI	51
25.	Pure Air	Advanced On-Site FGD Process.	FST	53
26.	Char-Fuels Associates, Ltd.	Dave Johnston CHARFUEL Demonstr.	FUP	55
27.	Southern Illinois University	Coal Mine/Prep. Waste Pwr. Plant	AFI	57
28.	Tennessee Valley Authority	160-MW AFBC Demo. Plant Test	AFU	59
29.	Montana State University	SO_2 and NO_x Removal with Petro.	FGC	61
30.	Staley Continental, Inc.	Decatur Repowering and Cogen.	AFU	63
31.	Tennessee Valley Authority	160-MW Hybrid AFBC Repowering	AFU	65
32.	Ultrasystems Engineers & Constr.	SCR to Control NO_x from Exist.	FGN	67
33.	Sunlaw Energy Corporation	Chanute IGCC Project	IGC	69
34.	NOXSO Corporation	NOXSO Flue Gas Cleanup Technol.	FGC	71
35.	M-C Power Corporation	IMHEX Molten Carbonate Fuel Cells	IGC	73
36.	Coal Dynamics Corporation	Burnout & Elec. Energy Prod.	ADC	75
37.	Allison Gas Turbine Division/GM	Venice Advanced PFB Demonstration	PFB	77
38.	Manitowoc Public Utilities	Manitowoc CCT Repowering Project	AFU	79
39.	Modular Power Plant Ltd. Partner	Homer City Modular Fluid. Bed	AFU	81
40.	Virginia Electric and Power Co.	Integ. Coal Cleaning/Circ. FBC	CBT	83
41.	TransAlta Resources Invest. Corp.	Low NO_x/SO_x Burner Retrofit	ADC	85
42.	Minnesota Power	Coal Benef. Demo. - Hot Water	FUP	87
43.	Duquesne Light Company	Coal Optimization Process	CBT	89
44.	CYCLEAN, INC.	Microwave Applications for CCT	CPR	93
45.	CLI Corporation	Advanced Integrated Fine Coal	CPR	95
46.	Otisca Industries, Ltd.	Prod. of Compl. OTISCA FUEL	CPR	97
47.	Energy Partners, Inc.	Retro. Ind. Boiler w/TAS Coal	ADC	99
48.	Northern States Power Company	An Integrated Post-Combustion	FST	101
49.	Lignite Research Council	Fluid. Bed Cogen. w/Great Plains	AFU	103
50.	En-R-Tech International, Inc.	En-R-Tech Clean Coal Emiss. Prog.	ADC	105
51.	Tallahassee, City of, Florida	Arvah B. Hopkins Stn. Repowering	AFU	107
52.	K-Fuel Partnership	Coal Process. Util. the K-Fuel	FUP	109
53.	Cool Water Coal Gasification	Cool Water Coal Gasif. Extend	IGC	111
54.	Helipump Corporation	Inno. NO_x & SO_x Control	FGC	113
55.	Carbonic International, Inc.	Flue Gas Separation Plant.	MSC	115

LIST OF PROPOSALS RECEIVED, IN ALPHABETICAL ORDER BY OFFEROR NAME

Offeror	Proposal Number	Abbreviated Project Title	Technology
Allison Gas Turbine Division/GM	37	Venice Advanced PFB Demonstration	PFB
American Electric Power Serv. Co.	18	PFBC Repowering Project	PFB
Babcock & Wilcox Co.	11	Coal Reburning for Cyclone Boil.	FGN
Babcock & Wilcox Co.	20	5-MWe Demo. of SOX-NOX-ROX Box	FGC
Babcock & Wilcox Co.	21	Furnace Limestone Injection	FSI
Babcock & Wilcox Co.	22	Demo. of Low-NO_x Cell Burner	FGN
Bechtel National, Inc.	24	Confined Zone Dispersion FGD	FSI
Bethlehem Steel Corporation	19	Coke Oven Gas Cleaning System.	IND
Calderon Energy Co.	15	Repower. via Novel IGCC Proc.	IGC
Carbonic International, Inc.	55	Flue Gas Separation Plant.	MSC
Char-Fuels Associates, Ltd.	26	Dave Johnston CHARFUEL Demonstr.	FUP
CLI Corporation	45	Advanced Integrated Fine Coal	CPR
Coal Dynamics Corporation	36	Burnout & Elec. Energy Prod.	ADC
Cogentrix/Coastal Joint Venture	23	The Williamsburg Project.	ADC
Combustion Engineering, Inc.	5	Pulv. Coal NO_x Reduct. Reburn	FGN
Combustion Engineering, Inc.	6	Post-Comb. Dry Sorbent Inject.	FSI
Combustion Engineering, Inc.	7	C.E. Gasification Repowering	IGC
Combustion Engineering, Inc.	9	Commer. Demo. of WSA-SNOX Tech.	FGC
Cool Water Coal Gasification	53	Cool Water Coal Gasif. Extend	IGC
CYCLEAN, INC.	44	Microwave Applications for CCT	CPR
Duquesne Light Company	43	Coal Optimization Process	CBT
Energy Partners, Inc.	47	Retro. Ind. Boiler w/TAS Coal	ADC
En-R-Tech International, Inc.	50	En-R-Tech Clean Coal Emiss. Prog.	ADC
Florida Power & Light Company	8	Florida Coal Gasification	IGC
Frontier Energy Corp.	10	Coal/Heavy Oil Hydrogenation	MSC
Helipump Corporation	54	Inno. NO_x & SO_x Control	FGC
Independence, City of, Missouri	14	Repower Blue Valley Power Plant	AFU
K-Fuel Partnership	52	Coal Process. Util. the K-Fuel	FUP
Lignite Research Council	49	Fluid. Bed Cogen. w/Great Plains	AFU
M-C Power Corporation	35	IMHEX Molten Carbonate Fuel Cells	IGC
Manitowoc Public Utilities	38	Manitowoc CCT Repowering Project	AFU
Minnesota Power	42	Coal Benef. Demo. - Hot Water	FUP
Modular Power Plant Ltd. Partner	39	Homer City Modular Fluid. Bed	AFU
Montana State University	29	SO_2 and NO_x Removal with Petro.	FGC
Northern States Power Company	48	An Integrated Post-Combustion	FST
NOXSO Corporation	34	NOXSO Flue Gas Cleanup Technol.	FGC
Otisca Industries, Ltd.	46	Prod. of Compl. OTISCA FUEL	CPR
Passamoquoddy Tribe	17	Passamaquoddy ICCT Prog. Appli.	IND
Pedco, Inc.	12	Ind. Demo. Pedco Rotary Cascad.	AFI
Pure Air	25	Advanced On-Site FGD Process.	FST
Southern Company Services, Inc.	1	100 MW Demo. of Technol.	FST
Southern Company Services, Inc.	2	500 MW Demo. of Adv. Wall-Fire	FGN
Southern Company Services, Inc.	3	Demo. of SCR for Control of NO_x	FGN
Southern Company Services, Inc.	4	Comb. Techn. for Reduct. NO_x	FGN
Southern Illinois University	27	Coal Mine/Prep. Waste Pwr. Plant	AFI
Southwestern Public Service Co.	16	Circ. Fluid-Bed Repowering	AFU
Staley Continental, Inc.	30	Decatur Repowering and Cogen.	AFU
Sunlaw Energy Corporation	33	Chanute IGCC Project	IGC
Tallahassee, City of, Florida	51	Arvah B. Hopkins Stn. Repowering	AFU
Tennessee Valley Authority	31	160-MW Hybrid AFBC Repowering	AFU
Tennessee Valley Authority	28	160-MW AFBC Demo. Plant Test	AFU
TransAlta Resources Invest. Corp.	41	Low NO_x/SO_x Burner Retrofit	ADC
Ultrasystems Engineers & Constr.	32	SCR to Control NO_x from Exist.	FGN
Virginia Electric and Power Co.	40	Integ. Coal Cleaning/Circ. FBC	CBT
Western Energy Company	13	Adv. Coal Conversion Process	FUP

CODES USED TO DESIGNATE TECHNOLOGY		
Technology	**Subcategory**	**Code**
Advanced Combustion	—	ADC
Coal Processing	Coal Preparation	CPR
	Fuel Upgrading	FUP
Combined Technologies	—	CBT
Flue Gas Cleanup	Combined SO_2/NO_x Control	FGC
	NO_x Control	FGN
	Sulfur Control–Injection	FSI
	Sulfur Control–Tailgas	FST
Fluidized-Bed Combustion (FBC)	Atmospheric FBC–Industrial	AFI
	Atmospheric FBC–Utility	AFU
	Pressurized FBC	PFB
Industrial Processes	—	IND
Integrated Gasification	Combined-Cycle (IGCC)	IGC
Miscellaneous	—	MSC

PROJECT SUMMARY

Proposal: 1

Offeror: Southern Company Services, Inc.

Title: 100-MW Demonstration of Innovative Applications of Technology for Cost Reductions to the Chiyoda Thoroughbred-121 Flue Gas Desulfurization Process on High-Sulfur, Coal-Fired Boilers.

Project Summary:

The proposed project would demonstrate a 100-MWe-size unit of the Chiyoda Thoroughbred-121 (CT-121) flue gas desulfurization (FGD) process. This process uses a unique absorber design known as the jet bubbling reactor (JBR). This reactor combines limestone FGD reactions, forced oxidation, and gypsum crystallization in one process vessel. As a result, the process is mechanically and chemically simpler than conventional FGD processes and thus can be expected to exhibit lower cost characteristics. Innovations to this process will be evaluated to determine whether costs can be reduced further, including the use of fiberglass reinforced plastic (FRP) absorbers, elimination of flue gas reheat and a spare absorber module, and gypsum stacking to reduce waste management costs. It is anticipated that these innovations will significantly reduce CT-121 costs in retrofit applications. Furthermore, existing data indicates that the process can simultaneously remove particulates to below the current New Source Performance Standard (NSPS) requirement of 0.03 lb/MMBtu. The ability of this technology to remove particulates will also be evaluated in the proposed demonstration.

The host site for the proposed demonstration project is the 100-MWe Plant Yates Unit 1 of Georgia Power Company located in Newnan, 40 miles southwest of Atlanta, Georgia. A 2.9% sulfur coal will be used for the demonstration. Project objectives include the demonstration of 90% SO_2 control at high reliability with and without simultaneous particulate control. In addition, extensive groundwater monitoring of the gypsum stacking area will be conducted, and a subcontract will be issued to the University of Georgia for the evaluation of use of the gypsum waste as an agricultural soil conditioner.

PROPOSAL NUMBER 2: SUMMARY PROJECT INFORMATION

Proposer:	Southern Company Services, Inc.
Proposal Title:	500-MW Demonstration of Advanced Wall-Fired Combustion Techniques for the Reduction of Nitrogen Oxide (NO_x) Emissions from Coal-Fired Boilers
Project Location:	Georgia Power Company's Plant Hammond, Coosa (near Rome), Floyd County, GA
Technology:	Combustion techniques for NO_x control
Type of Coal to be Used:	WV, TN, KY, and VA (multiple seams) 1.5-2.5% sulfur
Project Size:	500 MWe
Project Duration:	36 months
Offeror's Proposed Cost Share:	51.2%
Project Team Members:	Southern Company Services, Inc. Georgia Power Co. EPRI

PROJECT SUMMARY

Proposal: 2

Offeror: Southern Company Services, Inc.

Title: 500-MW Demonstration of Advanced Wall-Fired Combustion Techniques for the Reduction of Nitrogen Oxide (NO_x) Emissions from Coal-Fired Boilers

Project Summary:

The proposed project is for the purpose of demonstrating three advanced NO_x control technologies for retrofitting wall-fired, pulverized-coal boilers. The three NO_x control technologies are: Advanced Overfire Air (AOFA), which consists of deep-stage, high-rate air injection; second generation low-NO_x burner (LNB); and LNB with AOFA. The advanced NO_x control technologies will be sequentially applied to a single furnace, sub-critical, wall-fired boiler at the Georgia Power Company's Plant Hammond Unit 4 in Coosa, near Rome, Georgia. The proposed 500-MWe demonstration boiler is representative of a large class of wall-fired boilers. Approximately 42% of the NO_x emissions of pre-NSPS boilers are produced by wall-fired boilers similar to the proposed demonstration boiler.

The performance and NO_x reduction capabilities of each advanced NO_x control technology will be evaluated separately first and then in combined operation on the same demonstration boiler. Each technology will be tested for at least 3 months under typical dynamic boiler operating conditions. This will provide long-term operation information for each technology for comparisons and evaluations.

PROPOSAL NUMBER 3: SUMMARY PROJECT INFORMATION

Proposer:	Southern Company Services, Inc.
Proposal Title:	Demonstration of Selective Catalytic Reduction (SCR) Technology for Control of Nitrogen Oxide (NO_x) Emissions from High-Sulfur, Coal-Fired Boilers
Project Location:	Gulf Power Company's Plant Crist (near Pensacola), Escambia County, FL
Technology:	SCR for NO_x control
Types of Coal to be Used:	IL, WV, AL, KY (primarily Illinois Nos. 5 and 6 and Pittsburgh No. 8), 2.6-3.1% sulfur
Project Size:	7.5 MWe
Project Duration:	54 months
Offeror's Proposed Cost Share:	51.7%
Project Team Members:	Southern Company Services, Inc. EPRI Gulf Power Company

PROJECT SUMMARY

Proposal: 3

Offeror: Southern Company Services, Inc.

Title: *Demonstration of Selective Catalytic Reduction (SCR) Technology for the Control of Nitrogen Oxide (NO_x) Emissions from High-Sulfur, Coal-Fired Boilers*

Project Summary:

The proposed project is for the purpose of demonstrating that a combination of combustion modification technology and Selective Catalytic Reduction (SCR) provides the most cost-effective means for reducing nitrogen oxide emissions from power plants. Since proven combustion modification technologies such as low-NO_x burners exist, the demonstration will focus only on the application of SCR to high-sulfur coals. The project will utilize commercially available catalyst modules to obtain data on catalyst activity and catalyst life that is representative of full-scale operation of the process on utility boilers burning high-sulfur American coals. Small size versions of commercial air preheaters will be used to obtain information on the impact of the technology on utility air preheaters and identify other potential problems in transferring current Japanese and German SCR technology to American coal-fired utility applications.

The demonstration plant will be located between Units 5 (75 MWe) and 6 (320 MWe) of Gulf Power Company's Plant Crist near Pensacola, Florida. This location allows access to flue gas from approximately 3% sulfur coal under a variety of different NO_x and particulate levels. The prototype demonstration plant will include three SCR/air preheater trains with 2-5 MWe capacity, which will be used to evaluate current commercial catalyst modules. Six smaller test units (0.05 MWe each) will be included to allow testing of advanced catalyst formulations. The demonstration size was chosen as the smallest size capable of testing commercial catalysts modules using appropriate space velocities and catalyst configurations.

Once SCR has been demonstrated to operate economically on high-sulfur American coals, it will represent a technology which has the capability to obtain 90% reduction of NO_x emissions for utility and industrial boilers. The technology can potentially be applied to all types of boilers, including cyclone-fired boilers which cannot be easily retrofitted with other developing NO_x control technologies.

PROPOSAL NUMBER 4: SUMMARY PROJECT INFORMATION

Proposer:	Southern Company Services, Inc.
Proposal Title:	180-MW Demonstration of Advanced Tangentially Fired Combustion Techniques for the Reduction of Nitrogen Oxide (NO_x) Emissions from Coal-Fired Boilers
Project Location:	Gulf Power Company's Plant Smith, Lynn Haven (near Panama City), Bay County, FL
Technology:	Combustion techniques for NOx control
Types of Coal to be Used:	IL, WV, AL, KY (Primarily Illinois Nos. 5 and 6 and Pittsburgh No. 8), 2.6-3.1% sulfur
Project Size:	180 MWe
Project Duration:	41 months
Offeror's Proposed Cost Share:	51.5%
Project Team Members:	Southern Company Services, Inc. Gulf Power Company EPRI

PROJECT SUMMARY

Proposal: 4

Offeror: Southern Company Services, Inc.

Title: 180-MW Demonstration of Advanced Tangentially Fired Combustion Techniques for the Reduction of Nitrogen Oxide (NO_x) Emissions from Coal-Fired Boilers

Project Summary:

The proposed project would demonstrate three advanced NO_x control technologies for tangentially fired, pulverized-coal boilers: advanced overfire air which consists of deep-stage, high-rate air injection; low-NO_x concentric fired systems; and advanced tangentially fired systems. The advanced NO_x control technologies will be sequentially applied to a single tangentially fired boiler at Unit 2 of Gulf Power Company's Plant Smith in Lynn Haven, Florida. The proposed 180-MWe demonstration boiler is representative of a large class of tangential boilers. Approximately 30% of NO_x emissions of pre-NSPS boilers are produced by tangential boilers similar to the proposed demonstration boiler.

The performance and NO_x reduction capabilities of each advanced NO_x reduction technology will be evaluated separately and then in combined operation in a logical sequence on a single reference demonstration boiler. Each technology will be tested for at least three months under typical dynamic boiler operating conditions. This will ensure an accurate, comparative measure of the long-term NO_x reduction capabilities of each technology under typical operating conditions.

PROPOSAL NUMBER 5: SUMMARY PROJECT INFORMATION

Proposer:	Combustion Engineering, Inc.
Proposal Title:	Demonstration of a Pulverized Coal NO_x Reduction Reburn System on a Cyclone Boiler--An Extension to a Current Gas Reburn Demonstration Program
Project Location:	Niles, Trumbull County, OH
Technology:	NO_x control/coal reburning
Types of Coal to be Used:	Ohio Nos. 3A, 4, 5, 6 and 7: Kittaning, Lower and Middle Kittaning
Project Size:	108 MWe
Project Duration:	50 months
Offeror's Proposed Cost Share:	50.0%
Project Team Members:	Combustion Engineering, Inc. Ohio Edison EPRI Ohio Coal Development Office

PROJECT SUMMARY

Proposal: 5

Offeror: Combustion Engineering, Inc.

Title: Demonstration of a Pulverized Coal NO_x Reduction Reburn System on a *Cyclone Boiler--An extension to a Current Gas Reburn Demonstration* Program

Project Summary:

The specific objective will be to demonstrate that coal can be used as a reburning fuel for reducing nitrogen oxides from a coal-fired cyclone boiler. The primary result of successful demonstration will be a reduction in oxides of nitrogen emissions from coal-fired cyclone boilers in the United States; reburning technology is the only in-furnace NO_x control technology that has been shown to be technically feasible for cyclone boilers.

Combustion Engineering, Inc., (C-E) is presently conducting a program for the Environmental Protection Agency/Gas Research Institute/Electric Power Research Institute to demonstrate the use of natural gas as a reburning fuel in a 108-MWe coal-fired cyclone boiler at Ohio Edison's Niles Station Unit No. 1. It is proposed that the same boiler be used to demonstrate the use of pulverized coal as a reburn fuel in this proposal. The project team will be composed of C-E, Energy Systems Associates, Physical Sciences Incorporated, and Massachusetts Institute of Technology. C-E will be the overall project manager for this program.

A successful demonstration of the coal reburn technology could result in achieving a 50% NO_x reduction with no resultant decrease in boiler efficiency. This technology is expected to be applicable to all coal cyclone plants larger than about 80 MWe.

PROPOSAL NUMBER 6: SUMMARY PROJECT INFORMATION

Proposer:	Combustion Engineering, Inc.
Proposal Title:	Demonstration Program for Post-Combustion Dry Sorbent Injection Technology
Project Location:	Yorktown, York County, VA
Technology:	In-duct injection, in-duct spray drying, and convective pass injection
Types of Coal to be Used:	Eastern bituminous
Project Size:	180 MWe
Project Duration(s):	64 months
Offeror's Proposed Cost Share:	50.0%
Project Team Members:	Combustion Engineering, Inc. Virginia Power Company EPRI

PROJECT SUMMARY

Proposal: 6

Offeror: Combustion Engineering, Inc.

Title: Demonstration Program for Post-Combustion Dry Sorbent Injection Technology

Project Summary:

The proposed project is for the purpose of demonstrating three dry sorbent injection technologies: in-duct injection, in-duct spray drying, and convective pass injection for flue gas desulfurization. Convective pass injection is also known as economizer injection. The technologies involve injecting a calcium-containing sorbent either into the convective pass of the furnace or into the duct between the air preheater and the particulate control device, normally either an electrostatic precipitator or fabric filter. The sulfur dioxide in the flue gas reacts with calcium to form dry chemical compounds, calcium sulfite and calcium sulfate, which are removed in the particulate control device along with fly ash.

This 180-MWe demonstration will be conducted by Combustion Engineering along with Virginia Electric and Power Company and other subcontractors and will be sited at an existing power plant, Yorktown Unit 2. The objectives of this program are (1) to demonstrate reduction in sulfur oxide emission from Yorktown No. 2 by 50% or greater using these technologies and (2) to provide technical, economic, environmental, and operating data to support commercialization of these technologies by the electric power generation industry.

PROPOSAL NUMBER 7: SUMMARY PROJECT INFORMATION

Proposer:	Combustion Engineering, Inc.
Proposal Title:	Combustion Engineering Innovative Clean Coal Gasification Repowering Project
Project Location:	City Water, Light and Power's Lakeside Station, Springfield, Sangamon County, IL Alternate: Kansas Power and Light, Shawnee County, KS Alternate: Montana Power, Yellowstone County, MO
Technology:	Integrated Gasification Combined-Cycle
Types of Coal to be Used:	Illinois (primary site)
Project Size:	20 tons/hr high-sulfur coal feed rate Products: 65 MWe and 12 tons/day sulfur
Project Duration:	108 months
Offeror's Proposed Cost Share:	50.1%
Project Team Members:	Combustion Engineering, Inc. City Water, Light and Power (Springfield, IL) Illinois Department of Energy and Natural Resources Montana Power Company (alternate utility) Kansas Power and Light (alternate utility) General Electric Company Salomon Brothers, Inc. MPG International, Inc.

PROJECT SUMMARY

Proposal: 7

Offeror: Combustion Engineering, Inc.

Title: Combustion Engineering Innovative Clean Coal Gasification Repowering Project

Project Summary:

This project would demonstrate Combustion Engineering's (C-E) pressurized, air-blown, entrained-flow coal gasification repowering technology on a commercial scale. The syngas is cleaned of sulfur and particulates and then combusted in a gas turbine (40 MWe) from which heat is recovered in a heat recovery steam generator (HRSG). Steam from the gasification process and the HRSG will be used to power an existing steam turbine (25 MWe). Sponsors for this project include Combustion Engineering; the State of Illinois; and City Water, Light and Power of Springfield, Illinois, with technical participation by General Electric and MPG International (owned by Lockheed International).

The project being proposed is to repower an existing steam turbine at the Lakeside Generating Station of City Water, Light and Power, Springfield, Illinois. Two units under consideration are Lakeside Units 4 and 5. These two 20-MWe steam turbines, formerly coal-powered, have been retired and are being considered for reactivation to meet future energy requirements. Under the proposed project, one or both of the units would be reactivated and supplied with steam from a C-E gasifier and waste heat boiler. About 40 MWe additional would be produced by a new gas turbine.

The facility will produce 65 MWe net of electricity via the combined-cycle mode and 12 tons/day of sulfur from a daily consumption of 480 tons of high-sulfur (2.5%) Illinois No. 5 coal.

PROPOSAL NUMBER 8: SUMMARY PROJECT INFORMATION

Proposer:	Florida Power & Light Company
Proposal Title:	The Florida Coal Gasification Advancement Project
Project Location:	Florida Power & Light Company's Martin Site (near Indiantown), Martin County, FL
Technology:	Coal gasification combined-cycle
Types of Coal to be Used:	Northern/Central Appalachian and Illinois basin
Project Size:	3,054 tons/day coal feed rate Products: 383 MWe and 76 long tons/day sulfur
Project Duration(s):	85 months
Offeror's Proposed Cost Share:	55.6%
Project Team Members:	Florida Power & Light Company Florida Coal Gasification, Inc. (subsidiary of Shell Oil Co.) EPRI

PROJECT SUMMARY

Proposal: 8

Offeror: Florida Power and Light Company

Title: Florida Coal Gasification Advancement Project

Project Summary:

The proposed project is for the purpose of demonstrating an advanced integrated coal gasification combined-cycle system for electric generation. The project will feature an oxygen blown, slagging, entrained flow Shell gasifier with dry coal feed, a gas clean-up system, and an advanced gas turbine with a 2,300 °F firing temperature.

This 383-MWe demonstration will be conducted jointly by subsidiaries of Florida Power & Light and Shell Oil Co. and will be sited at an existing Florida Power & Light 1,500-MWe power plant site in Martin County, 100 miles north of Miami. The demonstration will feature commercial equipment and modules and is supported by a data base developed from the operation of a 250-400 tons/day of coal prototype plant.

The objective of the proposed project is to demonstrate the Shell gasification system integrated with combined-cycle power generation to determine the validity of the projections of improved efficiency and lower cost. Projects of various capacities could be developed by using the 130-MWe gasifier module that will be demonstrated in the proposed project. Other applications for the system are cogeneration, refueling boilers, and retrofitting combustion turbines and combined cycles.

PROPOSAL NUMBER 9: SUMMARY PROJECT INFORMATION

Proposer:	Combustion Engineering, Inc. Snamprogetti U.S.A., Inc.
Proposal Title:	Commercial Demonstration of WSA-SNOX Technology
Project Location:	Niles, Trumbull County, OH
Technology:	Advanced Flue Gas Cleanup (Catalytic)
Types of Coal to be Used:	Ohio Nos. 3A, 4, 5, 6 and 7: Kittaning, Lower and Middle Kittaning
Project Size:	35 MWe and 42 tons/day (93.6 wt %) sulfuric acid
Project Duration(s):	45 months
Offeror's Proposed Cost Share:	50.0%
Project Team Members:	Combustion Engineering, Inc. Snamprogetti U.S.A., Inc. Haldor Topsoe A/S Ohio Edison Co. Ohio Coal Development Office

PROJECT SUMMARY

Proposal: 9

Offeror: Combustion Engineering, Inc., and Snamprogetti U.S.A., Inc.

Title: Commercial Demonstration of WSA-SNOX Technology

Project Summary:

The proposed project is for the purpose of demonstrating the WSA-SNOX technology for catalytically removing both SO_2 and NO_x from flue gas and producing a salable byproduct: concentrated sulfuric acid. No sorbents are used and no waste byproducts are formed. Two catalytic reactors are used to first remove NO_x by converting it to N_2 in an SCR reactor and then to oxidize the SO_2 to SO_3. The SO_3 is subsequently hydrated and then condensed as H_2SO_4 to eliminate the overlap in the "WSA tower."

The 35-MWe demonstration will be conducted by Combustion Engineering and Snamprogetti U.S.A. and will be sited at an existing power plant, Ohio Edison's Niles Station Boiler No. 2. The objective of this project is to demonstrate the WSA-SNOX technology on an electric power plant firing high-sulfur Ohio coal. The demonstration will feature full-scale components and modules.

After demonstration, the system will offer a technology that is applicable for retrofitting existing power plants as well as for new power plants at a relatively low capital cost. Additionally, this technology has the ability to remove the SO_2 and NO_x without generating the large amount of waste byproducts normally associated with more traditional flue gas cleanup technologies. At the completion of the proposed program, WSA-SNOX will be ready for commercialization.

PROPOSAL NUMBER 10: SUMMARY PROJECT INFORMATION

Proposer:	Frontier Energy Corporation
Proposal Title:	Coal/Heavy Oil Hydrogenation Plant: Co-Processing High Technology
Project Location:	West of Painsville and east of Mentor, Lake County, OH
Technology:	Coal/heavy oil co-processing
Types of Coal to be Used:	Ohio Nos. 5, 6, and 7 seams
Project Size:	1,128 tons/day coal feed rate
Project Duration:	48 months
Offeror's Proposed Cost Share:	60.0%
Project Team Members:	Frontier Energy Corporation Kilhearn, Ltd. Canadian Energy

PROJECT SUMMARY

Proposal: 10

Offeror: Frontier Energy Corporation

Title: Coal/Heavy Oil Hydrogenation Plant

Project Summary:

Frontier Energy Corporation of Ohio, in association with Canadian Energy and Kilborn Limited of Toronto, plan to build and operate a new 23,700-barrel/day Coal/Heavy Oil Hydrogenation Plant in Lake County, Ohio, west of Painsville. The demonstration project consists of a small commercial-scale co-processing facility to process concurrently Ohio high-sulfur content, high-volatile bituminous coal and western Canadian heavy oil (bitumen) to produce a high-quality, low-sulfur synthetic crude product.

The product will be sold to local petroleum refiners for final processing into transportation fuels or to petrochemical plant operators as feedstock. Alternatively, a lower quality, low-sulfur content liquid hydrocarbon product can be produced for use as fuel in a thermal power plant or industrial boiler.

The CCLC High Conversion Hydrogenation Technology (developed by Canadian Energy of Alberta, Canada), which is in an advanced stage of development, will be used in the demonstration project. As most of the sulfur and nitrogen contained in the feed coal and heavy oil are recovered as elemental sulfur and anhydrous ammonia, SO_2 and NO_x emissions are substantially reduced during the combustion of the liquid hydrocarbon product.

PROPOSAL NUMBER 11: SUMMARY PROJECT INFORMATION

Proposer:	The Babcock & Wilcox Company
Proposal Title:	5-MWe Demonstration of the SOX-NOX-ROX Box (SNRB) Process
Project Location:	Ohio Edison's R.E. Burger Power Station, Unit No. 5, Dilles Bottom, Belmont County, OH
Technology:	Combined SO_2/NO_x, and particulate control
Types of Coal to be Used:	Ohio bituminous coals
Project Size:	5 MWe
Project Duration:	37 months
Offeror's Proposed Cost Share:	54.2%
Project Team Members:	The Babcock and Wilcox Company Ohio Edison Company Ohio Coal Development Office EPRI Norton Company Chemical Process Products 3M, New Products Dept.

PROJECT SUMMARY

Proposal: 11

Offeror: The Babcock & Wilcox Company

Title: 5-MWe Demonstration of SOX-NOX-ROX Box (SNRB) Process

Project Summary:

The proposed project is a post-combustion flue gas cleanup demonstration of combined removal of SO_2, NO_x, and particulates. Ammonia and a calcium-based sorbent are injected upstream of a high-temperature baghouse. The sorbent reacts with SO_2 and is removed in the baghouse. In the presence of the selective catalytic reduction catalyst, NO_x is reduced by the NH_3 to nitrogen and water. Particulate removal is accomplished in the baghouse using high temperature bags.

This SOX-NOX-ROX Box concept will be demonstrated using a 5-MWe slipstream of flue gas at the R.E. Burger Station of Ohio Edison. Unit 5 of the station is a 158-MWe, pre-NSPS privileged-coal-fired boiler that uses an Ohio bituminous coal.

After demonstration, the system will offer a simple, cost-effective method for reducing SO_2, NO_x, and particulate emissions in a retrofittable design. It is estimated that SO_2 removals of about 70-90% can be achieved with NO_x removals of 90% and particulate removals exceeding 99% in a single unit.

PROPOSAL NUMBER 12: SUMMARY PROJECT INFORMATION

Proposer:	Pedco, Inc.
Proposal Title:	Industrial Demonstration of the Pedco Rotary Cascading Bed Boiler (RCBB)
Project Location:	Cincinnati, Hamilton County, OH
Technology:	Repowering--RCBB
Types of Coal to be Used:	OH, KY, PA, WV, IN, IL, and OK waste coal
Project Size:	0.625 ton/hr coal feed rate
Project Duration:	48 months
Offeror's Proposed Cost Share:	50.0%
Project Team Members:	Pedco, Inc. Ohio Coal Development Office PMC Specialties Group, Inc. University of Cincinnati

PROJECT SUMMARY

Proposal: 12

Offeror: Pedco, Inc.

Title: Industrial Demonstration of the Pedco Rotary Cascading Bed Boiler

Project Summary:

This proposal involves the installation and demonstration of a 10,000-lb/hr steam (1 MWe) rotary cascading bed boiler (RCBB) in a chemical plant as a third boiler. A 5,000-lb/hr steam boiler (0.42 MWe) was previously installed and demonstrated over a period of 1,400 hrs in a brewery with one long-duration run of 72 hours. The proposal request includes the following major objectives:

1. Modification, relocation, and operation of the 5,000-lb/hr industrial-scale RCBB. The RCBB will be relocated in an industrial location in Cincinnati, Ohio.

2. Completion of a test program to confirm, over a long period of time, the ability of the modified RCBB to meet the requirements for emission control and for combustion efficiency believed desirable for commercialization.

3. Operation for a period of at least 36 months in an industrial environment. During the operational period, it is planned to burn as wide a variety of coals as feasible. Emphasis will be given to burning marginal and waste coals in combination with other fuels and with some waste materials.

4. Design of a modular system incorporating information from the test program for industrial use including generation of electrical power and steam. This commercial system will be capable of supplying packaged boilers in the 10,000-60,000 lb/hr of steam capacity range.

PROPOSAL NUMBER 13: SUMMARY PROJECT INFORMATION

Proposer:	Western Energy Company
Proposal Title:	Advanced Coal Conversion Process Demonstration
Project Location:	Colstrip, Rosebud County, MT
Technology:	Advanced coal cleaning
Types of Coal to be Used:	Rosebud subbituminous, 1% sulfur
Project Size:	68 tons/hr coal feed rate
Project Duration:	59 months
Offeror's Proposed Cost Share:	50.4%
Project Team Members:	Western Energy Company Stone & Webster Engineering Corp.

PROJECT SUMMARY

Proposal: 13

Offeror: Western Energy Company

Title: Advanced Coal Conversion Process Demonstration

Project Summary:

The purpose of the proposed project is to demonstrate an advanced coal cleaning and processing facility using the Advanced Coal Conversion Process (ACCP) of Western Energy Company. The ACCP technology upgrades low-quality, high-moisture coals producing a product which is equivalent to clean, stable, high-quality, low moisture bituminous coals. This is a thermochemical process which uses low-pressure inert gas to heat raw coal in dual fluidized beds arranged in series. Heating the coal shrinks the moisture-holding capillaries in the coal and causes the destruction of moisture reaction sites. The shrinkage of the capillaries in the coal causes the ash and pyrite particles to be easily separated from the coal by simple gravity separation procedures. Such alterations to the raw coal result in a high-quality product which is cleaner and drier and has more desirable handling characteristics than the raw coal and other competitive coals, without the addition of chemical stabilizers or enhancers.

The demonstration plant will be a facility producing 45 tons/hr of the product (300,000 tons per year), scaled up from the current 200 lb/hr pilot facility. The ACCP dries the coal, liberates the ash particles, and converts the organic coal molecules to a denser structure that prevents water from being reabsorbed. A major benefit of the ACCP technology is that the cleanability of the low-rank coal is improved, allowing sulfur and ash removal after the conversion step is completed.

PROPOSAL NUMBER 14: SUMMARY PROJECT INFORMATION

Proposer:	City of Independence, Missouri
Proposal Title:	Repowering, Uprate, and Life Extend Blue Valley Power Plant Units 1 and 2
Project Location:	Independence, Jackson County, MO
Technology:	Combined-cycle circulating fluidized-bed combustion
Types of Coal to be Used:	Design coal--Missouri, bituminous, 3-5% sulfur
Project Size:	44 MWe repowering plus 54 MWe capacity increase, for a total of 98 MWe
Project Duration:	84 months
Offeror's Proposed Cost Share:	58.0%
Project Team Members:	Power and Light Department, City of Independence Stone & Webster Engineering Corp.

PROJECT SUMMARY

Proposal: 14

Offeror: City of Independence, Missouri

Title: Repower, Uprate and Life Extend Blue Valley Power Plant Units 1 and 2

Project Summary:

The City of Independence, Missouri, proposes to repower, extend life, and increase generation capacity at its Blue Valley generating plant. The technology proposed is a combined-cycle concept utilizing a coal-fired circulating fluid-bed (CFB) boiler with an air-cooled external fluid-bed heat exchanger (FBHE). As a result of repowering the Blue Valley facility, the generating capacity of the replaced Units 1 and 2 boilers will increase from 42 MWe to 100 MWe.

The proposed project includes a new coal-fired, 70-MWe CFB boiler to replace the existing Unit 1 and 2 boilers as part of an expansion of the existing power plant structure. The new CFB boiler will provide high-pressure steam to a newly installed topping turbine/generator in addition to providing reheated steam to the existing lower pressure Units 1 and 2 turbine/generators. An innovative feature of the proposed CFB boiler is the use of recycled solids in an external FBHE to preheat air for use with natural gas for expansion in a gas turbine/generator. The gas turbine/generator provides an additional 30 MWe of electric generation, and exhaust gases pass through a heat recovery system for preheating air to the CFB, thereby increasing plant combined-cycle efficiency. The combination of the fluid-bed combustor and the gas expansion turbine provide increased efficiency, fuel flexibility, and increased availability over a stand-alone fluid-bed combustor.

PROPOSAL NUMBER 15: SUMMARY PROJECT INFORMATION

Proposer:	Calderon Energy Company
Proposal Title:	Calderon Method for Repowering Coal-Burning Facilities via Novel Integrated Gasification/Combined Cycle (IGCC) Process which Economically Cogenerates Electric Power and Methanol
Project Location:	City of Bowling Green, Wood County, OH
Technology:	Repowering/IGCC-Methanol
Types of Coal to be Used:	High-sulfur (2.95%) Ohio coal
Project Size:	65 tons/hr coal feed rate Products: 87 MWe (net) and 613 tons/day methanol
Project Duration:	58 months
Offeror's Proposed Cost Share:	(Business confidential)
Project Team Members:	Calderon Energy Company Stearns-Roger Division, United Engineers & Constructors

PROJECT SUMMARY

Proposal: 15

Offeror: Calderon Energy Co.

Title: Calderon Method for Repowering Coal Burning Facilities via Novel Integrated Gasification/Combined Cycle Process which Economically Cogenerates Electric Power and Methanol

Project Summary:

Even though this technology is applicable to the repowering of existing coal burning facilities, the project will, for demonstration purposes, be built on a new (grass-roots) location in order to be unencumbered by other operating facilities. This project will be located in Bowling Green, Ohio, and will include a pressurized facility comprising the pyrolysis of run-of-mine coal, char gasification with air, regenerative hot gas cleanup, electric power generation, and methanol production.

The facility will coproduce 87 MWe net of electricity via the combined cycle mode and 613 tons of methanol per day from a daily consumption of 1,560 tons of high-sulfur (2.95%) Ohio coal.

PROPOSAL NUMBER 16: SUMMARY PROJECT INFORMATION

Proposer:	Southwestern Public Service Company
Proposal Title:	Nichols Station Unit 3 Circulating Fluidized-Bed Repowering Project
Project Location:	Nichols Station (northeast of Amarillo), Potter County, TX
Technology:	Circulating fluidized-bed combustion
Types of Coal to be Used:	Design coal: subbituminous, Powder River Basin coal Alternate: bituminous, Raton Basin coal Test coals: eastern Oklahoma bituminous, midwestern, Appalachian
Project Size:	256 MWe
Project Duration:	72 months
Offeror's Proposed Cost Share:	61.6%
Project Team Members:	Southwestern Public Service Company

PROJECT SUMMARY

Proposal: 16

Offeror: Southwestern Public Service Company

Title: Nichols Station Unit 3 Circulating Fluidized-Bed Repowering Project

Project Summary:

Southwestern Public Service Company is proposing to repower an existing 256-MWe steam turbine generator at the Nichols Station Power Plant, located near Amarillo, Texas, using a circulating fluidized-bed (CFB) boiler. This repowering project is intended to demonstrate the use of a scaled-up CFB boiler in order to promote commercialization of larger size CFB boilers than are presently available. The boiler will generate 1,800,000 lbs/hr of steam at 2,005 psi and 1,005 °F. The preheater will be of the heat pipe type-- a relatively new innovation in utility boiler applications. The CFB is scheduled to burn Wyoming and New Mexico subbituminous coal. There will be a 2-year test program after which the facility will continue to operate commercially.

PROPOSAL NUMBER 17: SUMMARY PROJECT INFORMATION

Proposer:	Passamaquoddy Tribe
Proposal Title:	Passamaquoddy Innovative Clean Coal Technology Program Application
Project Location:	Thomaston, Knox County, ME
Technology:	Recovery scrubber for removing SO_2 emissions
Types of Coal to be Used:	Any coal acceptable for cement kiln use
Project Size:	11.4 tons/hr coal feed rate
Project Duration:	36 months
Offeror's Proposed Cost Share:	50.0%
Project Team Members:	Passamaquoddy Tribe

PROJECT SUMMARY

Proposal: 17

Offeror: Passamaquoddy Tribe

Title: Passamaquoddy Innovative Clean Coal Technology Program Application

Project Summary:

The proposed project is for demonstrating a scrubbing system for removing SO_2 emissions from existing coal-burning cement kilns. The project features the Passamaquoddy Tribe's "Recovery Scrubber," which can reduce SO_2 emissions by over 90%, uses kiln waste dust as the scrubbing reagent, produces a recycle stream for feeding to the kiln, and generates two potentially salable byproducts (potassium-based fertilizer and distilled water), and generates no new wastes.

The demonstration will be conducted at the tribe's cement plant, Dragon Products Company, which is located in Thomaston, Maine. The demonstration will treat the entire gas stream from the cement kiln, which has a capacity of 470,000 tons/year of cement clinker. Currently the 250,000 cfm of kiln exhaust contains 300 ppm of SO_2. Byproduct recovery will be demonstrated through the use of a heat exchanger/evaporator.

The Recovery Scrubber, once it has been demonstrated, will enable the cement industry to operate their kilns on high-sulfur coal while reducing SO_2 emission levels, eliminating a solid waste stream, and producing salable byproducts.

PROPOSAL NUMBER 18: SUMMARY PROJECT INFORMATION

Proposer:	American Electric Power Service Corporation
Proposal Title:	Philip Sporn Plant PFBC Repowering Project
Project Location:	Philip Sporn Plant, New Haven, Mason County, WV
Technology:	Pressurized fluidized-bed combustion--combined cycle
Types of Coal to be Used:	High and low sulfur (1-4%)
Project Size:	330 MWe
Project Duration:	95 months
Offeror's Proposed Cost Share:	68.1%
Project Team Members:	American Electric Power Service Corporation ASEA-Babcock

PROJECT SUMMARY

Proposal: 18

Offeror: American Electric Power Service Corporation (AEPSC)

Title: Philip Sporn Plant PFBC Repowering Project

Project Summary:

AEPSC proposes to repower two commercially operating 150-MW pulverized coal-fired electric generating units of early 1950's vintage, by replacing the two boilers with a single pressurized fluidized-bed (PFB) combustor/gas turbine module capable of generating 330 MW. The net thermal efficiency of the repowered plant will be about 38% (with SO_2 and NO_x control); this compares with the present efficiency of 36.5% (without O_2 and NO_x control). Specific performance objectives when burning high-sulfur (4%) coal are expected to result in greater than 90% sulfur retention and less than 0.3 lb NO_x emissions per million Btu.

The project is based on more than 10 years of development work by AEP on PFB technology and will build upon the experience gained from the 70-MW Tidd PFB Demonstration Plant currently under construction under the Clean Coal Technology-I program. Design of the Sporn repowering project is expected to begin in late 1989, and start-up is scheduled for late 1995. A 1.5-year demonstration period is planned.

PROPOSAL NUMBER 19: SUMMARY PROJECT INFORMATION

Proposer:	Bethlehem Steel Corporation
Proposal Title:	Innovative Coke Oven Gas Cleaning System for Retrofit Applications
Project Location:	Bethlehem Steel's Sparrows Point Plant, Baltimore County, MD
Technology:	Coke oven gas cleaning
Types of Coal to be Used:	High volatile (Pittsburgh No. 8), 1.33% sulfur; Low volatile (Lower Kittaning-B), 0.9% sulfur
Project Size:	5,687 tons/hr coal feed rate
Project Duration:	39 months
Offeror's Proposed Cost Share:	61.1%
Project Team Members:	Bethlehem Steel Corporation Davy/Still-Otto

PROJECT SUMMARY

Proposal: 19

Offeror: Bethlehem Steel Corporation

Title: Innovative Coke Oven Gas Cleaning System for Retrofit Applications

Project Summary:

This proposal addresses the modification of the existing coke gas cleaning plant (coal chemical plant) at the Bethlehem Steel Sparrows Point, Maryland, steel plant which consists of two coke batteries. The coke oven gas (COG) from the smaller of the two batteries is recycled directly to the coke ovens without chemical recovery or cleanup. The COG from the larger of the two batteries undergoes both chemical recovery and cleanup prior to its use as a fuel gas in various plant operations. The current process configuration for cleaning COG at Sparrows Point consists of the following systems:

- o Sulfur removal--Sulfur in the form of H_2S is removed from the processed COG stream using a carbonate contact process and converted to elemental sulfur in a Claus plant for subsequent sale.
- o Ammonia removal--Ammonia is removed as ammonium sulfate in a saturator after reaction with H_2SO_4 and is subsequently sold.
- o Benzene and other air emissions--Direct contact water associated with naphthalene separation and final gas cooling is cooled in an atmospheric cooling tower resulting in significant benzene, ammonia, HCN, and other volatile organic compounds emissions.

Under the proposed project, the COG processing would be changed as follows:

- o The COG would be cooled using a recirculating liquor with a (closed) indirect cooling tower thus eliminating the benzene and other emissions associated with the atmospheric final gas cooling tower now in use.
- o Ammonia and H_2S would be removed by absorption into an ammonia liquid solution with subsequent steam stripping of the combined H_2S and ammonia vapors. This stream is then passed to a system where the ammonia is catalytically destroyed (i.e., converted to H_2 and N_2), and a portion of the H_2S is oxidized to SO_2 for input to the Claus plant as a combined H_2S/SO_2 stream.
- o The COG that streams from both coke batteries would be processed with this system.

PROPOSAL NUMBER 20: SUMMARY PROJECT INFORMATION

Proposer:	The Babcock & Wilcox Company
Proposal Title:	Full-Scale Demonstration of Low-NO_x Cell Burner Retrofit
Project Location:	Ohio Edison's W.H. Sammis Plant, Unit No. 6, Stratton, Jefferson County, OH
Technology:	Low-NO_x cell burners retrofit
Types of Coal to be Used:	Ohio bituminous coals, 2-3% sulfur
Project Size:	234.5 tons/hr coal feed rate (after retrofitting) 600 MWe
Project Duration:	32 months
Offeror's Proposed Cost Share:	54.0%
Project Team Members:	The Babcock & Wilcox Company Ohio Edison Company Ohio Coal Development Office Duke Power Company EPRI

PROJECT SUMMARY

Proposal: 20

Offeror: The Babcock & Wilcox Company

Title: Full-Scale Demonstration of Low-NO_x Cell Burner Retrofit

Project Summary:

The objective of this project is to demonstrate the cost-effective reduction of NO_x emissions from a large, base-loaded, coal-fired utility boiler by retrofitting it with low-NO_x cell burners. The focus of the demonstration is to maximize NO_x reduction without degradation of boiler performance.

All 24 standard two-nozzle, cell-type burners in Ohio Edison's W.H. Sammis Plant, Unit No. 6, will be replaced with low-NO_x cell burners. Sammis Unit No. 6, located in Stratton, Ohio, is a pre-NSPS, 600-MWe Babcock & Wilcox (B&W) supercritical, once-through unit equipped with an electrostatic precipitator.

Generating units equipped with pulverized-coal-fired, cell-type burners account for over 26,000 MWe of U.S. electric power generating capacity. Coal-fired generating units equipped with cell-type burners produce almost 15% of the pre-NSPS utility NO_x emissions. B&W has developed low-NO_x cell burners that may reduce NO_x emissions from these units by 50% with no resultant decrease in boiler efficiency.

PROPOSAL NUMBER 21: SUMMARY PROJECT INFORMATION

Proposer:	The Babcock & Wilcox Company
Proposal Title:	Demonstration of Coal Reburning for Cyclone Boiler NO_x Control
Project Location:	Wisconsin Power & Light Company's Nelson Dewey Plant, Unit No. 2, Cassville, Grant County, WI
Technology:	NO_x control/coal reburning
Types of Coal to be Used:	Eastern bituminous coal
Project Size:	42 tons/hr coal feed rate 100 MWe
Project Duration:	43 months
Offeror's Proposed Cost Share:	50.0%
Project Team Members:	The Babcock & Wilcox Company Wisconsin Power & Light Company EPRI Illinois Department of Energy

PROJECT SUMMARY

Proposal: 21

Offeror: The Babcock & Wilcox Company

Title: Demonstration of Coal Reburning for Cyclone Boiler NO_x Control

Project Summary:

The specific objective of the project is to demonstrate that coal can be used as a reburning fuel for reducing nitrogen oxides on a coal-fired cyclone boiler. The primary result of successful demonstration and subsequent commercialization will be a reduction in oxides of nitrogen emissions from coal-fired cyclone boilers in the United States; reburning technology is the only in-furnace NO_x control technology that has been shown to be technically feasible for cyclone boilers.

A coal reburning retrofit will be designed, fabricated, and installed in Wisconsin Power & Light Company's Nelson Dewey Plant Unit No. 2, which is located along the Mississippi River in Cassville, Wisconsin. This unit is a pre-NSPS, 100-MWe Babcock & Wilcox cyclone boiler unit equipped with an electrostatic precipitator. Pilot scale testing and mathematical modeling will be utilized in the retrofit design.

A successful demonstration of the coal reburning technology could result in achieving a 50% NO_x with no resultant decrease in boiler efficiency. This technology is expected to be applicable to all cyclone boilers larger than about 80 MWe.

PROPOSAL NUMBER 22: SUMMARY PROJECT INFORMATION

Proposer:	The Babcock & Wilcox Company
Proposal Title:	Furnace Limestone Injection, Dry Scrubbing
Project Location:	Ohio Edison Company's R.E. Burger Station, Dilles Bottom, Belmont County, OH
Technology:	Flue gas desulfurization; SO_x control/limestone *injection*
Types of Coal to be Used:	Bituminous, medium to high sulfur
Project Size:	62.5 tons/hr coal feed rate 156 MWe
Project Duration:	56 months
Offeror's Proposed Cost Share:	50.0%
Project Team Members:	The Babcock & Wilcox Company Ohio Edison Company Ohio Coal Development Office EPRI

PROJECT SUMMARY

Proposal: 22

Offeror: The Babcock & Wilcox Company

Title: Furnace Limestone Injection, Dry Scrubbing

Project Summary:

The proposed project would demonstrate the integration of two existing technologies, furnace limestone injection and dry scrubbing, for the control of SO_2 emissions from existing coal-fired boilers. Limestone is injected into the boiler above the combustion zone where it calcines to quicklime. A portion of the quicklime reacts with the SO_2 to form calcium sulfate. A mixture of calcium sulfate, unreacted quicklime, and flash is captured in the electrostatic precipitator, slurried with water and introduced into a dry scrubber where additional SO_2 removal occurs. The primary advantages of the integrated process as compared to a conventional dry scrubber are:

- Partial SO_2 removal in the boiler reduces the SO_2 removal requirement in the dry scrubber

- Limestone is used as the sorbent instead of lime which is required for a conventional dry scrubber. Lime costs are approximately four times those of limestone.

The demonstration site is Ohio Edison's R.E. Burger Station located at Dilles Bottom in Belmont County, Ohio. Unit No. 5, rated at 156 MWe, would be used to evaluate a commercial-scale module of the integrated process. Coal sulfur content typically used in this plant is on the order of 3.0-3.5%. The objectives of the proposed project are to demonstrate overall SO_2 removal efficiencies of 75-85% (30-40% in the boilers and 65-75% in the dry scrubber) while maintaining compliance with existing particulate emission standards.

PROPOSAL NUMBER 23: SUMMARY PROJECT INFORMATION

Proposer:	Cogentrix/Coastal Joint Venture
Proposal Title:	The Williamsburg Project
Project Location:	Williamsburg, James City County, VA
Technology:	Combined coal/limestone micropulverization
Types of Coal to be Used:	High-sulfur bituminous
Project Size:	47 tons/hr coal feed rate 110 MWe cogeneration facility
Project Duration:	47 months
Offeror's Proposed Cost Share:	58.5%
Project Team Members:	Cogentrix/Coastal Joint Venture Ergon, Inc.

PROJECT SUMMARY

Proposal: 23

Offeror: Cogentrix/Coastal Joint Venture

Title: The Williamsburg Project

Project Summary:

The proposer plans to construct a new 110-MWe cogeneration facility in Williamsburg, Virginia, which will burn high-sulfur eastern bituminous coal to produce electricity and process steam. Virginia Power Company is the potential purchaser of the electrical output and BASF Corporation Fibers Division is the potential purchaser of the steam output.

The facility will be composed of six stoker boilers to be fitted with Foster Wheeler low-NO_x burners above the grates. The units will be powered by micronized coal mixed with limestone at a calcium to sulfur ratio of 2. Exhaust particulate removal will be accomplished using bag filters.

The key feature of the facility is the coal micropulverizer which has been under development over the last 10 years and is currently being tested in a joint cost-shared program by the Cogentrix/Coastal Joint Venture and the U.S. Department of Energy's Pittsburgh Energy Technology Center (DOE Contract No. DE-AC22-88PC88650).

The combustion characteristics of the micropulverized coal are similar to those of gas and oil. Thus this fuel would also be compatible with furnaces originally designed for gas or oil. In new applications, modules of smaller size steam generators fired with micropulverized coal would be less expensive than today's conventional coal-fired steam generators.

PROPOSAL NUMBER 24: SUMMARY PROJECT INFORMATION

Proposer:	Bechtel National, Inc.
Proposal Title:	Confined Zone Dispersion Flue Gas Desulfurization Demonstration
Project Location:	Seward Station, Seward (near Johnstown), Indiana County, PA
Technology:	Flue gas desulfurization; atomized lime slurry injection/dispersion
Types of Coal to be Used:	Bituminous, upper Freeport, 1.2-2.5% sulfur
Project Size:	140 MWe
Project Duration:	24 months
Offeror's Proposed Cost Share:	50.0%
Project Team Members:	Bechtel National, Inc. Pennsylvania Electric Company Pennsylvania Energy Development Authority

PROJECT SUMMARY

Proposal: 24

Offeror: Bechtel National, Inc.

Title: Confined Zone Dispersion Flue Gas Desulfurization Demonstration

Project Summary:

The proposed project would demonstrate the Confined Zone Dispersion (CZD) process for the control of SO_2 from existing coal-fired boilers. The CZD process involves the injection of finely atomized sprays of lime slurry into the flue gas duct between the air preheater and the electrostatic precipitator (ESP). The lime reacts with the SO_2 to form a solid waste product which is captured in the ESP along with the fly-ash. Pilot scale tests sponsored by DOE indicated that SO_2 removals in excess of 50% could be achieved using either dolomite or calcitic lime slurries. Some limited additional testing was later performed in a 70-MWe duct of a Pennsylvania Electric Company (Penelec) commercial boiler at the Seward Station.

The proposed demonstration program provides for additional testing and evaluation of the CZD process at Penelec's Seward Station located near Johnstown, Pennsylvania. The test duct at the Seward plant is only forty feet in length thus providing a limited residence time. The proposed project would attempt to increase SO_2 removal to 50% by injecting the slurry in two stages. Another test objective is to demonstrate that the desired level of SO_2 control can be achieved without exceeding existing particulate emission standards. This plant normally burns a 1.4% sulfur coal. However, a variance will be sought in order to evaluate the process for a 3-4 week period with a higher sulfur coal.

PROPOSAL NUMBER 25: SUMMARY PROJECT INFORMATION

Proposer:	Pure Air
Proposal Title:	Advanced On-Site Flue Gas Desulfurization Process
Project Location:	Northern Indiana Public Service Company's Dean H. Mitchell Station, Gary, Lake County, IN
Technology:	Flue gas desulfurization
Types of Coal to be Used:	High sulfur: 2.9% sulfur to 4.5% sulfur
Project Size:	529 MWe
Project Duration:	68 months
Offeror's Proposed Cost Share:	55.0%
Project Team Members:	Pure Air (Joint venture of Air Products and Chemicals, Inc., and Mitsubishi Heavy Industries America, Inc.) Northern Indiana Public Service Company

PROJECT SUMMARY

Proposal: 25

Offeror: Pure Air

Title: Advanced On-Site Flue Gas Desulfurization Process

Project Summary:

The proposed project would demonstrate a commercial scale advanced limestone scrubber flue gas desulfurization (FGD) system. A single, 529-MWe absorber module will treat the flue gas from four existing boilers. The expected high reliability will permit operation without the use of spare absorber modules. The system design will use a high velocity, cocurrent flow absorber with direct injection of pulverized limestone. The system design includes a new and innovative single-loop process which produces commercial gypsum, using in-situ forced oxidation accomplished by a rotary air sparger. A novel waste water evaporation system will be evaluated that potentially eliminates water disposal/treatment problems associated with the use of high chloride content coals and essentially provides no water discharge. A cyclic reheater will be used to reduce the operating costs normally associated with stream reheat. The overall goal of the project is to demonstrate that the innovative features of the proposed approach combined with by-product gypsum sales will result in a system capable of 90% or higher SO_2 capture at a cost that is 50% lower than that which can be achieved by currently available FGD systems. The project also intends to demonstrate that the FGD system can be owned and operated by a separate company.

The proposed demonstration site is the Northern Indiana Public Service Company's (NIPSCO) Dean H. Mitchell Station, located in Gary, Indiana. This plant currently burns a 4.5% sulfur coal. Other coals will also be evaluated. Following the three year demonstration period, Pure Air and NIPSCO intend to consummate an agreement where Pure Air will continue to own and operate the FGD facility for an additional 17 years.

PROPOSAL NUMBER 26: SUMMARY PROJECT INFORMATION

Proposer:	Char-Fuels Associates, Ltd.
Proposal Title:	Dave Johnston CHARFUEL[tm] Demonstration Project
Project Location:	Pacific Power & Light's Dave Johnston Station, Glenrock, WY
Technology:	Coal refining with on-site retrofit
Types of Coal to be Used:	School seam, 0.49% sulfur
Project Size:	150 tons/day (moisture, ash free) increasing to 1,000 tons/day 100 MWe
Project Duration:	86 months
Offeror's Proposed Cost Share:	56.4%
Project Team Members:	Char-Fuels Associates, Ltd. Carbon Fuels Corp. (Parent of CFA) Pacific Power & Light State of Wyoming

PROJECT SUMMARY

Proposal: 26

Offeror: Char-Fuels Associates, Ltd. (CFA)

Title: Dave Johnston CHARFUEL^{tm} Demonstration Project

Project Summary:

The project would involve designing, constructing, and operating a demonstration/ commercial prototype CHARFUEL production facility and commercial burns of the products produced from various coals in a retrofitted 100-MW boiler operated by Pacific Power and Light. The CHARFUEL process, a pre-combustion clean coal technology, is a thermal volatilization process where pulverized coal is rapidly heated in a reducing atmosphere in the presence of process hydrogen. The process operates on the petroleum refining principle of "rearranging" molecular structures and selectively transferring inherent hydrogen away from certain carbons (yielding char) to other carbons (yielding gases or liquids). Downstream cleanup of the gas and treatment of liquids follows.

The char and low viscosity, high-Btu hydrocarbon liquids are blended to yield the CHARFUEL slurry, a manufactured, compliance fuel which can be produced for a particular boiler's fuel specifications. In addition to the CHARFUEL slurry, the process also yields the following byproducts: (1) elemental sulfur, (2) ammonia, (3) BTX, (4) naphtha, (5) methanol, (6) MTBE, and (7) carbon dioxide.

PROPOSAL NUMBER 27: SUMMARY PROJECT INFORMATION

Proposer:	Southern Illinois University at Carbondale
Proposal Title:	Coal Mine/Preparation Waste Fueled Power Plant Expansion at Southern Illinois University at Carbondale, Carbondale, IL
Project Location:	Southern Illinois University at Carbondale, Jackson County, IL
Technology:	Fluidized-bed combustion of coal mine/preparation waste
Types of Coal to be Used:	Coal mine/preparation wastes and Illinois coal
Project Size:	18.7 tons/hr coal mining and preparation waste Products: 140,000 lb/hr steam and 3.5 MWe
Project Duration:	60 months
Offeror's Proposed Cost Share:	50.4%
Project Team Members:	Southern Illinois University at Carbondale/State of Illinois Board of Higher Education Sargent & Lundy Central Illinois Public Service Company, Power Production Department Sega, Inc. Combustion Power Company, Inc. Peabody Holding Company, Inc. Illinois Department of Energy

PROJECT SUMMARY

Proposal: 27

Offeror: Southern Illinois University at Carbondale

Title: Coal Mine/Preparation Waste Fueled Power Plant Expansion at Southern Illinois University at Carbondale, Carbondale, Illinois

Project Summary:

The Southern Illinois University proposes to repower and extend their existing facility with a fluidized-bed boiler plant, material handling facilities to feed differing coals and coal wastes to the boiler, a new ash-handling system, and to add a steam turbine-generator. The project is designed to provide 3.5 MWe of electricity and 140,000 lbs/hr of steam to the campus.

The project will demonstrate the burning of both Illinois washed coal and preparation plant wastes. The primary fuel will be a washing waste dredged from a slurry pit. The slurry contains very fine coal, has low Btu content, high ash, and fairly high sulfur content. Burning of other wastes, such as coarse preparation wastes, could also be demonstrated at the facility.

PROPOSAL NUMBER 28: SUMMARY PROJECT INFORMATION

Proposer:	Tennessee Valley Authority
Proposal Title:	160-MW AFBC Demonstration Plant Test Program
Project Location:	TVA's Shawnee Steam Plant, West Paducah, McCraken County, KY
Technology:	Atmospheric fluidized-bed combustion
Types of Coal to be Used:	Primarily eastern high-sulfur bituminous
Project Size:	160 MWe
Project Duration:	48 months
Offeror's Proposed Cost Share:	79.8%
Project Team Members:	Tennessee Valley Authority

PROJECT SUMMARY

Proposal: 28

Offeror: Tennessee Valley Authority

Title: 160-MW AFB Demonstration Plant Test Program

Project Summary:

The Tennessee Valley Authority (TVA) proposes to demonstrate, on a commercial scale, the economic and environmental acceptability of an atmospheric fluidized-bed (AFB) boiler to produce the steam necessary for the production of electricity. Achievement of this goal will demonstrate the capability of AFB technology to: (1) improve unit performance and reliability, (2) meet and exceed environmental regulations, (3) provide electricity at a competitive cost, and (4) use a variety of coals.

The demonstration unit is currently under construction at TVA's Shawnee Steam Plant in Paducah, Kentucky. The AFB boiler, nominally rated at 160 MWe, would repower existing Unit 10 and utilize that unit's turbine generator set. Construction is scheduled to be completed in 1988.

It is the goal of TVA's project to demonstrate the economical and commercial viability of AFB on a utility scale. In order to meet this goal, an extensive test program, divided into two major test periods, will be conducted as follows:

- Parametric Evaluation--Two years of limited parametric testing to determine performance over a range of operating conditions. During this test period, plans are to use four alternative fuels.

- Extended Demonstration--two years of extended demonstration while the unit is on economic dispatch to allow evaluation of plant performance and reliability in a commercial environment.

PROPOSAL NUMBER 29: SUMMARY PROJECT INFORMATION

Proposer:	Montana State University
Proposal Title:	SO_2 and NO_x Removal
Project Location:	Montana State University, Bozeman, MT
Technology:	Flue gas cleanup
Types of Coal to be Used:	(Not specified)
Project Size:	Laboratory-scale unit
Project Duration:	12 months
Offeror's Proposed Cost Share:	50.0%
Project Team Members:	Montana State University

PROJECT SUMMARY

Proposal: 29

Offeror: Department of Chemical Engineering, Montana State University

Title: SO_2 and NO_x Removal with Petroleum Pitch

Project Summary:

The proposed project would demonstrate a method of removing SO_2 and NO_x from the stack gases of coal burning power plants. Current lime scrubbers are difficult to operate and maintain on a continuous basis, the lime slurry is hard to dispose of, and thus the additional cost of electricity caused by this cleanup requirement is considerable. The process to be developed consists of treating the SO_2/NO_x mixture with petroleum pitch.

The first portion of this project would be devoted to laboratory research, performed at the Department of Chemical Engineering, Montana State University. The conditions under which petroleum pitch would remove SO_2 and NO_x from the flue gas mixture will be determined.

A reactor system will be built in which the SO_2/NO_x-containing flue gas will be subjected to the molten pitch. The treated flue gas will be analyzed to determine the effectiveness of the pitch in removing the SO_2 and NO_x. In addition, the role of catalyst additions to the pitch to enhance its reactivity relative to the SO_2 and NO_x will be investigated. The feasibility of recovering sulfur and nitrogen from the pitch will also be investigated.

PROPOSAL NUMBER 30: SUMMARY PROJECT INFORMATION

Proposer:	Staley Continental, Inc.
Proposal Title:	Decatur Plant Utilities Repowering and Cogeneration Demonstration Project
Project Location:	Decatur, Macon County, IL
Technology:	Multi-solids fluidized-bed combustion
Types of Coal to be Used:	High-sulfur, high-volatile bituminous
Project Size:	55 MWe
Project Duration:	45 months
Offeror's Proposed Cost Share:	83.2%
Project Team Members:	A.E. Staley Manufacturing, Division of Staley Continental, Inc.

PROJECT SUMMARY

Proposal: 30

Offeror: Staley Continental, Inc.

Title: Decatur Plant Utilities Repowering and Cogeneration Demonstration Project

Project Summary:

The purpose of the project is to demonstrate a Riley Stoker Multisolids Fluidized-Bed (MSFB) combustion steam generator at the Staley corn processing plant. A unique feature of the MSFB is the dense bed which grinds and mixes the fuel as it burns and allows the acceptance of a coal feed as large as 2 inches. Limestone sorbent of 1/4 inch in size is also added with the coal into the dense bed along with ash and sand which serves as a medium to transport heat to an external heat exchanger.

Staley is proposing to conduct a test program in one of its two new 375,000 lb/hr steam generators. The test program would consist of burning multiple fuels, while varying the sorbents to determine the applicability of the MSFB technology for utility plant repowering.

PROPOSAL NUMBER 31: SUMMARY PROJECT INFORMATION

Proposer:	*Tennessee Valley Authority*
Proposal Title:	Hybrid AFBC Repowering Project
Project Location:	TVA's Shawnee Fossil Plant Reservation, McCraken County, KY
Technology:	Hybrid atmospheric fluidized-bed combustor
Types of Coal to be Used:	High-sulfur (4.5%)
Project Size:	160 MWe
Project Duration:	72 months
Offeror's Proposed Cost Share:	50.0%
Project Team Members:	Tennessee Valley Authority

PROJECT SUMMARY

Proposal: 31

Offeror: Tennessee Valley Authority

Title: Hybrid Atmospheric Fluidized Bed Combustion (AFBC) Repowering Project

Project Summary:

The proposed project is to design, construct, and operate over a 4-year test period a 160-MWe hybrid AFBC demonstration plant. To accomplish the demonstration, Unit 9 of the Tennessee Valley Authority's Shawnee Fossil Plant will be repowered with a hybrid fluidized-bed (HFB) boiler while retaining use of the existing turbine generator and much of the plant's auxiliary equipment.

The goal of the proposed project is to demonstrate that the hybrid AFBC technology can be used to economically repower a wide selection of existing coal-fired utility boilers in the 100-500 MWe range. The hybrid fluidized-bed boiler uses a higher fluidizing bed velocity to reduce bed plan area and internal furnace ash/gas separators to minimize the upper furnace and convective pass envelope.

The HFB repowering concept seeks to maximize the use of existing boiler pressure components, auxiliaries, and balance of plant facilities, thereby reducing the capital cost of repowering with a minimum of construction downtime.

PROPOSAL NUMBER 32: SUMMARY PROJECT INFORMATION

Proposer:	Ultrasystems Engineers & Constructors, Inc.
Proposal Title:	Pilot Project Demonstrating Use of Selective Catalytic Reduction to Control NO_x Emissions from an Existing Cyclone Electric Utility Boiler Firing High-Sulfur Illinois Coal
Project Location:	Coffeen Unit 2, Coffeen Power Station, Montgomery County, IL
Technology:	Selective Catalytic Reduction (SCR)
Types of Coal to be Used:	High-sulfur Illinois No. 6
Project Size:	0.7 tons/hr coal feed rate 1.7 MWe
Project Duration:	36 months
Offeror's Proposed Cost Share:	50.0%
Project Team Members:	Ultrasystems Engineers & Constructors, Inc. Nippon Shokubai Kagaku Kogyo Company, Ltd. Central Illinois Public Service Company Illinois Department of Energy

PROJECT SUMMARY

Proposal: 32

Offeror: Ultrasystems Engineers & Constructors, Inc.

Title: Pilot Project Demonstrating Use of Selective Catalytic Reduction (SCR) to Control NO_x Emissions from an Existing Cyclone Electric Utility Boiler Firing High-Sulfur Illinois Coal

Project Summary:

The proposed project is for the purpose of demonstrating Selective Catalytic Reduction (SCR) as a cost-effective means for significantly reducing NO_x emissions from utility boilers. The project will utilize commercially available catalyst modules to obtain data on catalyst activity and catalyst life representative of commercial operation of the process on utility boilers burning high-sulfur, high-chloride, American coals. A deposition probe section will also be used to obtain information on the impact of the technology on utility preheaters.

A nominal 1.7-MWe demonstration will be conducted by Ultrasystems Engineers and Constructors, Inc., in cooperation with Nippon Shokubai Kagaku Kogyo Co., Ltd., Central Illinois Public Services Co., and the State of Illinois. The project will be conducted at the Coffeen Power Station in South Central Illinois using a flue gas slip stream from the 550-MWe Coffeen Unit No. 2. The demonstration size was chosen to be the minimum and sufficient size for testing commercial catalysts using appropriate space velocities and catalyst configurations.

Once SCR has been demonstrated to operate on high-sulfur American coals it will represent a technology which has the capability to obtain 90% reduction of NO_x emissions for utility and industrial boilers. The technology can be applied to all types of dry-bottom boilers. The technology can also be applied to cyclone-fired boilers which cannot be easily retrofitted with other developing NO_x control technologies.

PROPOSAL NUMBER 33: SUMMARY PROJECT INFORMATION

Proposer:	Sunlaw Energy Corporation
Proposal Title:	Chanute Air Force Base Integrated Gasification Combined-Cycle Project (Chanute IGCC Project)
Project Location:	Chanute Air Force Base, Rantoul, Champaign County, IL
Technology:	Integrated gasification combined-cycle (IGCC)
Types of Coal to be Used:	Illinois No. 6
Project Size:	14 tons/hr coal feed rate Products: 94 MWe and 48,000 lb/hr steam
Project Duration:	87 months
Offeror's Proposed Cost Share:	50.0%
Project Team Members:	Sunlaw Energy Corporation Institute of Gas Technology Illinois Department of Energy Peabody Holding Company, Inc.

PROJECT SUMMARY

Proposal: 33

Offeror: Sunlaw Energy Corporation

Title: Chanute Air Force Base Integrated Gasification Combined-Cycle Project (Chanute IGCC Project)

Project Summary:

The proposed project is for a modification of an ongoing cogeneration project. This existing project will utilize three natural gas-fired, LM-2500 gas turbines and one steam turbine in a combined-cycle configuration to provide both steam and electricity to Chanute Air Force Base in Rantoul, Illinois. This existing project is currently in the design stage.

The proposed demonstration project would modify part of the overall cogeneration system to an IGCC configuration firing one of the gas turbines on coal-derived, low-Btu fuel gas. The proposed project would convert 330 tons/day of high-sulfur Illinois bituminous coal into a total of 32 MWe of electric power. The project will use the Institute of Gas Technology's air-blown, high-pressure, ash agglomerating fluidized-bed gasification process (U-GAS) using in-bed desulfurization; an advanced "hot gas cleanup" system for particulate and sulfur control; and an LM-2500 gas turbine-based, combined-cycle power system.

The project will use the pressurized (230 psia) U-GAS process to gasify coal with air to produce low-Btu gas (140-150 Btu/scf). Dolomite will be injected into the gasifier for *in situ* removal of sulfur. The coal ash and the spent dolomite will be discharged as a non-leachable residue. The product gas from the gasifier will be treated by a hot gas cleanup system containing high efficiency filtration units, such as ceramic candle filters, and a zinc ferrite polishing sulfur removal step. The hot clean product gas will be raised to gas turbine firing pressure using a booster compressor and used as a fuel in one of the gas turbines in the cogeneration system.

PROPOSAL NUMBER 34: SUMMARY PROJECT INFORMATION

Proposer:	NOXSO Corporation
Proposal Title:	NOXSO Innovative Flue Gas Cleanup Technology Demonstration Project
Project Location:	Toronto, Jefferson County, OH
Technology:	NOXSO flue gas cleanup process
Types of Coal to be Used:	Pittsburgh No. 8 and Ohio No. 6A
Project Size:	65 MWe
Project Duration:	49 months
Offeror's Proposed Cost Share:	50.0%
Project Team Members:	MK-Ferguson Company W.R. Grace & Company NOXSO Corporation Ohio Edison Company Ohio Coal Development Office

PROJECT SUMMARY

Proposal: 34

Offeror: NOXSO Corporation

Title: NOXSO Innovative Flue Gas Cleanup Technology Demonstration Project

Project Summary:

The proposed project would demonstrate a full-scale module (200,000 scfm of flue gas) of the NOXSO process for the simultaneous reduction of SO_2 and NO_x emissions from coal-fired boilers. This is a dry exothermic process that produces a marketable product and no waste streams. The host site for the proposed demonstration is Ohio Edison's Toronto, Ohio, power plant where an existing 65-MWe boiler would be retrofitted. The objectives of the project are to demonstrate 90% removal of both SO_2 and NO_x during integrated operation at a commercial scale.

PROPOSAL NUMBER 35: SUMMARY PROJECT INFORMATION

Proposer:	M-C Power Corporation
Proposal Title:	Coal-fired IMHEX Molten Carbonate Fuel Cells for Combined-Cycle Repowering
Project Location:	IGT Energy Development Center, Chicago, Cook County, IL
Technology:	Molten carbonate fuel cells
Types of Coal to be Used:	(Business confidential)
Project Size:	500 kWe
Project Duration:	58 months
Offeror's Proposed Cost Share:	(Business confidential)
Project Team Members:	M-C Power Corporation Institute of Gas Technology Illinois Department of Energy and Natural Resources EPRI Combustion Engineering, Inc.

PROJECT SUMMARY

Proposal: 35

Offeror: M-C Power Corporation

Title: Coal-fired IMHEX Molten Carbonate Fuel Cells for Combined-Cycle Repowering

Project Summary:

The proposed project would demonstrate coal gasification with product gas cleanup and molten carbonate fuel cells for electric power generation. The project will utilize an existing fluidized-bed U-GAS gasifier, a cold gas cleanup system, and two 250-kWe molten carbonate fuel cell modules and will be located at the Institute of Gas Technology facility in Chicago.

PROPOSAL NUMBER 36: SUMMARY PROJECT INFORMATION

Proposer:	Coal Dynamics Corporation
Proposal Title:	Controlled Burnout and Electrical Energy Production of the Plummer-Puritan Mine Fire, Fayette County, Pennsylvania
Project Location:	Village of Leckrone, Germantown Township, Fayette County, PA
Technology:	Controlled Burnout Power Generation
Types of Coal to be Used:	Bituminous, Pittsburgh No. 8, 0.79% sulfur, 12,200 Btu/lb
Project Size:	15 MWe gross
Project Duration:	48 months
Offeror's Proposed Cost Share:	53.6%
Project Team Members:	Coal Dynamics Corporation

PROJECT SUMMARY

Proposal: 36

Offeror: Coal Dynamics Corporation

Title: Controlled Burnout and Electrical Energy Production of the Plummer-Puritan Mine Fire, Fayette County, Pennsylvania

Project Summary:

The technology proposed for demonstration is the utilization of modular conventional heat recovery steam generators and small steam turbines to generate electrical power from existing fires in abandoned coal mines.

The approach is based on "controlled burn-out" technology investigated by the Bureau of Mines to mitigate the hazards associated with fires in abandoned mines. It involves penetrating the mine workings with a bore hole/induced draft fan system (and additional bore holes for ingestion of air if necessary) to accelerate the rate at which the remaining coal is burned, and to remove the products of combustion at a single point.

The proposed project would demonstrate application of the controlled burn with energy recovery by including small boilers and steam turbine generator systems. The demonstration site would be the Plummer-Puritan mine fire in Fayette County, Pennsylvania, and could generate up to 20 MWe. The project would focus on an initial 7-MWe system.

PROPOSAL NUMBER 37: SUMMARY PROJECT INFORMATION

Proposer:	Allison Gas Turbine Division, General Motors Corporation
Proposal Title:	Venice Advanced Pressurized Fluidized-Bed Combustors (PFBC) Demonstration Project
Project Location:	Venice, Madison County, IL
Technology:	Advanced PFBC
Types of Coal to be Used:	High-sulfur midwestern coals
Project Size:	(Business confidential)
Project Duration:	(Business confidential)
Offeror's Proposed Cost Share:	(Business confidential)
Project Team Members:	Allison Gas Turbine Division, General Motors Corporation Union Electric Company Foster Wheeler Development Corporation Bechtel North American Power Company Illinois Office of Coal Development & Marketing Illinois Dept. of Energy and Natural Resources AMAX Coal Enterprises, Inc. Industrial Filter and Pump Manufacturing Company EPRI

PROJECT SUMMARY

Proposal: 37

Offeror: Allison Gas Turbine Division, General Motors Corporation

Title: Venice Advanced PFBC Demonstration Project

Project Summary:

This project would be located at the Union Electric utility plant in Venice, Illinois.

The project is a demonstration for commercial/industrial applications and will also serve as a prototype of a combined-cycle for electric utility power plants.

The process concept begins with coal being fed to a pressurized carbonizer that produces a low-Btu fuel gas for a gas turbine combustor and char. The char is fed to a pressurized fluid-bed combustor (PFBC) which produces hot, pressurized flue gas. The low-Btu fuel gas is mixed with the hot flue gas, which contains free oxygen, and burned in a topping combustor. Cyclones and high efficiency filters clean the gases from the carbonizer and PFBC to protect the turbine and meet ambient particulate requirements. Calcium-based sorbent is used for sulfur capture in both units.

The Venice project would provide design and operating data for commercial industrial-size plants and a modularized approach to a utility plant application.

PROPOSAL NUMBER 38: SUMMARY PROJECT INFORMATION

Proposer:	Manitowoc Public Utilities
Proposal Title:	Manitowoc Public Utilities Clean Coal Technology Repowering Project via Atmospheric Circulating Fluidized-Bed Combustion (AFBC)
Project Location:	Manitowoc, Manitowoc County, WI
Technology:	Atmospheric fluidized-bed combustion
Types of Coal to be Used:	High-sulfur, midwestern U.S. coals
Project Size:	20 tons/hr coal feed rate 22 MWe
Project Duration:	50 months
Offeror's Proposed Cost Share:	60.4%
Project Team Members:	Manitowoc Public Utilities

PROJECT SUMMARY

Proposal: 38

Offeror: Manitowoc Public Utilities

Title: Manitowoc Public Utilities Clean Coal Technology Repowering Project via AFBC

Project Summary:

The Manitowoc Public Utilities proposes to construct and operate a 200,000 lb/hr atmospheric circulating fluidized-bed (ACFB) boiler in Manitowoc, Wisconsin, located on Lake Michigan approximately 75 miles north of Milwaukee, Wisconsin. The objective of this project is to demonstrate ACFB technology in a repowering mode for small to medium size electric utility and industrial application.

The Manitowoc Public Utilities proposes to add the ACFB to its conventional coal-fired electric power generating plant. High-sulfur coal from adjacent states will be used as fuel for this addition. Also, locally mined dolomitic limestone will be used in the unit.

As part of this project, the Manitowoc Public Utilities proposes to use the unit to test coals and limestone from various parts of the United States and, thereby, demonstrate the full range and capability of this technology to substantially reduce air emissions.

PROPOSAL NUMBER 39: SUMMARY PROJECT INFORMATION

Proposer:	Modular Power Plant Limited Partnership
Proposal Title:	Homer City Modular Fluidized-Bed Power Plant Project
Project Location:	Homer City, Indiana County, PA
Technology:	Circulating fluidized-bed combustion
Types of Coal to be Used:	Waste coal material, 0.5-3% sulfur
Project Size:	17 MWe
Project Duration:	84 months
Offeror's Proposed Cost Share:	54.4%
Project Team Members:	Modular Power Plant Limited Partnership Rubenstein Engineering, P.C. J.A. Jones Construction Company Deutsch Babcock

PROJECT SUMMARY

Proposal: 39

Offeror: Modular Power Plant Limited Partnership

Title: Homer City Modular Fluidized-Bed Power Plant Project

Project Summary:

An atmospheric pressure, circulating fluidized-bed boiler (CFBC) with freeboard tubes for steam generation followed by cyclonic particle separation and solids recycle is proposed for this project. The two key design features of the proposed coal-fired boiler technology are modularity and compactness. Modularity is said to comprise a very large fraction of factory (as opposed to field) fabrication at reduced cost. Compactness is expected to facilitate repowering and provide broader applicability due to reduced "foot print" requirements and also produce a favorable influence on cost.

This project, located on the site of the former DOE BI-GAS facility at Homer City in Indiana County, Pennsylvania, will consist of a 17-MWe modular atmospheric fluidized-bed power plant which will burn high-ash, high-moisture, waste bituminous coal with a range of low to high sulfur content in an environmentally acceptable manner. The project proposes to utilize the coal handling and water treatment facilities, the fire protection infrastructure, the waste treatment facility, and other components and buildings still existing at the site. The 140,000 lb/hr (17 MWe) Deutsche-Babcock Circofluid fluidized-bed boiler will be delivered in three major sections and assembled at the site.

PROPOSAL NUMBER 40: SUMMARY PROJECT INFORMATION

Proposer:	Virginia Electric and Power Company
Proposal Title:	Integrated Coal Cleaning/Circulating Fluidized-Bed Combustion Demonstration at the Mt. Storm Power Station, West Virginia Energy Center
Project Location:	Mt. Storm Power Station, Grant and Tucker Counties, WV
Technology:	Integration of multiproduct coal cleaning and fluidized-bed combustion
Types of Coal to be Used:	Bituminous coal
Project Size:	773 tons/hr raw coal feed to coal cleaning plant 125 MWe (CFB)
Project Duration:	90 months
Offeror's Proposed Cost Share:	60.0%
Project Team Members:	Virginia Electric and Power Company EPRI Island Creek Corporation

PROJECT SUMMARY

Proposal: 40

Offeror: Virginia Electric and Power Company (Virginia Power)

Title: Integrated Coal Cleaning/Circulating Fluidized-Bed Combustion Demonstration at the Mt. Storm Power Station, West Virginia Energy Center

Project Summary:

The proposed demonstration project consists of a combination of retrofitting and repowering technologies--precombustion coal cleaning and circulating fluidized-bed (CFB) combustion--to reduce existing SO_2 emissions at the Mt. Storm Power Station at the West Virginia Energy Center while providing a 125-MWe net increase in total plant power generating capacity. The objective of this project is to demonstrate the successful integration of two clean coal technologies. This demonstration project will verify the improved performance achievable by integrating coal cleaning with CFB combustion. These two technologies are directed toward achieving a more economical and beneficial use of coal while obtaining increased power generation with lower SO_2 emissions. The deep-cleaned, low-sulfur coal would be used in an existing pulverized coal boiler to lower SO_2 emissions while the CFB power generating system would be fueled by the middling coal from the coal preparation plant. The coal preparation plant would result in a Btu recovery improvement of between 73% and 91%. The plant would have a smooth pore filter that, if successful, would offer an alternative to the use of SO_2 generating thermal dryers and at the same time accomplish efficient fine coal recovery.

PROPOSAL NUMBER 41: SUMMARY PROJECT INFORMATION

Proposer:	TransAlta Resources Investment Corporation
Proposal Title:	Low NO_x/SO_x Burner Retrofit for Utility Cyclone Boilers
Project Location:	Marion, Williamson County, IL
Technology:	Retrofit, advanced combustion
Types of Coal to be Used:	Midwestern high-sulfur bituminous
Project Size:	20 tons/hr coal feed rate 33 MWe
Project Duration:	21 months
Offeror's Proposed Cost Share:	50.0%
Project Team Members:	TransAlta Resources Investment Corporation Illinois Department of Energy EPRI Southern Illinois Power Cooperative

PROJECT SUMMARY

Proposal: 41

Offeror: TransAlta Resources Investment Corporation

Title: Low NO_x/SO_x Burner Retrofit for Utility Cyclone Boilers

Project Summary:

The project would retrofit and demonstrate a low NO_x/SO_x (LNS) Burner and a coal pulverizer system on the 33-MWe unit/cyclone boiler at Southern Illinois Power Cooperative's Marion Plant. Two LNS burners, each rated at 200 million Btu/hr, will retrofit the existing Babcock & Wilcox cyclones.

Development of the LNS Burner Technology was initiated by Rockwell International in 1979 with theories suggesting a high removal of the SO_2 and NO_x produced during combustion could be controlled. TransAlta acquired the LNS burner technology from Rockwell International in 1986 and is continuing with the development of the technology.

PROPOSAL NUMBER 42: SUMMARY PROJECT INFORMATION

Proposer:	Minnesota Power
Proposal Title:	Coal Beneficiation Demonstration: Hot Water Drying Technology
Project Location:	Clay Boswell Steam Electric Station, Cohasset, MN
Technology:	Coal cleaning by beneficiation
Types of Coal to be Used:	Rosebud subbituminous coal
Project Size:	50 tons/hr coal feed rate 12 tons/hr coal product
Project Duration:	(Not specified)
Offeror's Proposed Cost Share:	(Not specified)
Project Team Members:	Minnesota Power Bechtel National, Inc. Peabody Holding Company

PROJECT SUMMARY

Proposal: 42

Offeror: Minnesota Power

Title: Coal Beneficiation Demonstration Hot Water Drying Technology

Project Summary:

The proposed coal demonstration plant would be located at the Clay Boswell Steam Electric Station, Cohasset, Minnesota. The beneficiation plant would be designed to operate primarily on Rosebud subbituminous coal, a coal located in Montana and Wyoming.

Hot water drying is the process by which water and some mineral matter is removed from coal by (1) immersing coal in water, (2) raising the pressure and temperature of the mixture, (3) allowing sufficient residence time for the reactions to adequately proceed, and (4) separating the solid coal, carbon dioxide gas, and the wastewater.

Hot water drying has the potential to upgrade low-rank, low-sulfur coals to a higher rank coal, essentially synthesizing a bituminous coal. This technology could be used in the 1990s to beneficiate a utility's main fuel supply, possibly lowering the production cost of electricity while simultaneously reducing sulfur emissions.

PROPOSAL NUMBER 43: SUMMARY PROJECT INFORMATION

Proposer:	Duquesne Light Company
Proposal Title:	Coal Optimization Process for Emission Reduction (COPER Project)
Project Location:	Warwick Mine, Greensboro, Greene and Allegheny Counties, PA
Technology:	Coal Cleaning and post-combustion emissions control
Types of Coal to be Used:	Northern Appalachian and midwestern
Project Size:	600 tons/hr coal feed rate
Project Duration:	72 months
Offeror's Proposed Cost Share:	50.0%
Project Team Members:	Duquesne Light Company EPRI

PROJECT SUMMARY

Proposal: 43

Offeror: Duquesne Light Company

Title: Coal Optimization Process for Emissions Reduction (COPER Project)

Project Summary:

This proposed project consists of investigating and comparing the effectiveness and economics of three coal cleaning approaches integrated with various post-combustion emission control techniques. Coal will be cleaned to three quality levels using each of three approaches:

1. Conventional coal cleaning (as currently performed by Duquesne Light Company's Warwick Cleaning Plant).

2. "State-of-the-art" coal cleaning, which will involve the use of the best commercially available coal cleaning technology.

3. Innovative coal cleaning technology, which includes the use of advanced froth flotation on the coal fines, and incorporation of on-line control technology.

An integral part of the project is to study power plant performance and emissions by firing clean coal produced through these three approaches. The test plant will be Duquesne Light's 565-MWe Cheswick Power Plant located northeast of Pittsburgh, Pennsylvania. The demonstration project includes the construction of a new coal cleaning plant and provides for testing and demonstrating the impacts on the Cheswick plant of various clean coals produced by the plant from raw coal mined in different regions of the United States.

A 600-ton/hr coal cleaning facility will be designed and constructed at the Duquesne Light Company's Warwick Mine to process coal from the Sewickley Coal Seam. This plant will process coal from an existing coal cleaning operation and will incorporate a split flotation design with fine grinding and froth flotation for separation of micron-sized pyritic material to reduce the sulfur content. This plant will be sized to supply the requirements for the 565-MWe Cheswick Power Plant. It will be designed to operate as a conventional, "state-of-the-art" modern, or advanced coal cleaning plant, with the capability to process the normal supply of coal from the Sewickley Seam, a variety of other coals, and ultimately, to include test work for other companies.

PROPOSAL NUMBER 44: SUMMARY PROJECT INFORMATION

Proposer:	CYCLEAN, INC.
Proposal Title:	Microwave Applications for Clean Coal Technologies
Project Location:	Georgetown, Williamson County, TX
Technology:	On-site retrofit
Types of Coal to be Used:	High-sulfur coals
Project Size:	(Business confidential)
Project Duration:	(Business confidential)
Offeror's Proposed Cost Share:	(Business confidential)
Project Team Members:	CYCLEAN, INC. Western Illinois Power Cooperative, Inc. Illinois Department of Energy

PROJECT SUMMARY

Proposal: 44

Offeror: CYCLEAN, INC.

Title: Microwave Applications for Clean Coal Technologies

Project Summary:

The purpose of the proposed project is to demonstrate the feasibility of applying microwave technology to coal desulfurization. The project will feature a powerful microwave funnel capable of treating a large quantity of coal using a microwave source operating at 915 megahertz. The CYCLEAN process is based on General Electric's early reports that the microwave irradiation of finely ground dry coal results in selective heating (and subsequent decomposition) of pyrite without significantly raising the bulk temperature of coal.

Gaseous products resulting from the decomposition of pyrite are reacted with lime in a small fluidized-bed reactor to form $CaSO_4$. The claimed sulfur removal potential of CYCLEAN's microwave process is 50% of the pyritic sulfur present in coal.

For the purpose of the demonstration, a microwave coal processor will be installed next to one of the existing coal pulverizers in the Western Illinois Power Company's plant located in Pearl, Illinois.

PROPOSAL NUMBER 45: SUMMARY PROJECT INFORMATION

Proposer:	CLI Corporation
Proposal Title:	Advanced Integrated Fine Coal Cleaning Process
Project Location:	Labelle Processing Company, Labelle, Fayette County, PA
Technology:	Physical and chemical fine coal cleaning
Types of Coal to be Used:	Lower Kittaning (2% sulfur), Illinois No. 6 (3% sulfur), Elkhorn (1.5% sulfur), Taggart Seam (1.5% sulfur), Mary Lee (1% sulfur), Pittsburgh No. 8 (3% sulfur), Upper Freeport Coal (2.5% sulfur)
Project Size:	10 tons/hr coal feed rate for 100-mesh coal and 1 ton/hr for chemical coal cleaning Product: 10 tons/hr coal-water slurry (dry coal basis) flow rate
Project Duration:	42 months
Offeror's Proposed Cost Share:	50.0%
Project Team Members:	CLI Corporation LaBelle Processing Company Jim Walter Resources, Inc., Mining Division Pennsylvania State University White Industries Limited, CSIRO & ACIRL (Joint Venture) Pennsylvania Mine Services Northern Continental Operating Co., Inc.

PROJECT SUMMARY

Proposal: 45

Offeror: CLI Corporation

Title: Advanced Integrated Fine Coal Cleaning Process

Project Summary:

The intent of the proposed project is to demonstrate advanced coal preparation technologies for cleaning fine coal in an integrated process in which both physical and chemical processing of coal will be utilized, separately or in combination, to produce a mix of products from a single coal preparation facility. This approach combines the low-cost physical processing with higher-cost chemical cleaning to minimize overall production cost.

The proposed process utilizes the three advanced technology unit operations coupled with state-of-the-art coal preparation technology. The advanced coal preparation technology includes:

1. Fine coal cleaning of minus 100-mesh coal utilizing suspensions of micronized magnetite as the medium. Cleaning in commercially available dense-medium cyclones coupled with commercially available equipment from other industries to micronize magnetite and to recover micronized magnetite for reuse as medium.

2. Chemical coal cleaning of 4 mm x 0 raw, prepared or middling coals, utilizing a proprietary process developed by CSIRO of Australia and licensed to the proposer. The process reduces ash to levels as low as 0.2%, thereby reducing pyritic sulfur levels to essentially zero. The chemical coal cleaning process is to be used to produce low-ash, low-sulfur products for combustion processes where the cost-benefit of utilizing an ultra-clean product as a fuel or feedstock can be justified.

3. Coal-water slurry to transport and provide a "liquid fuel" for industrial users requiring a replacement low-sulfur, low-ash fuel that is compatible with existing oil- or gas-fired combustion equipment.

For the proposed demonstration, the technologies will retrofit an existing 1,200-ton/hr coal preparation plant (Labelle Coal Preparation Plant in southwestern Pennsylvania) which has the capability for cleaning plus 28-mesh coal in dense-medium vessels and cyclones, and which has the infrastructure in place to receive a wide range of raw coals, distribute products, and dispose of waste material.

PROPOSAL NUMBER 46: SUMMARY PROJECT INFORMATION

Proposer:	Otisca Industries, Ltd.
Proposal Title:	Production of Compliance OTISCA FUEL (Coal/Water Slurry) from High Ash and Sulfur Coal and its Combustion in Retrofitted Industrial Boilers
Project Location:	Syracuse, Onondaga County, NY; Jamesville, Onondaga County, NY; Oneida, Oneida County, NY
Technology:	Coal/water slurry
Types of Coal to be Used:	Eastern bituminous, Taggart seam
Project Size:	40,000 dry tons/yr of OTISCA FUEL
Project Duration:	24 months
Offeror's Proposed Cost Share:	50.0%
Project Team Members:	Otisca Industries, Ltd.

PROJECT SUMMARY

Proposal: 46

Offeror: Otisca Industries, Ltd.

Title: Production of Compliance OTISCA FUEL (Coal/Water Slurry) from High Ash and Sulfur Coal and its Combustion in Retrofitted Industrial Boilers

Project Summary:

The purpose of the proposed project is to demonstrate the manufacture, storage, handling, and utilization of an ultra clean coal/water slurry (CWS), known as OTISCA FUEL. The core of the manufacturing process for OTISCA FUEL is the Otisca-T Process, which consists of reducing the raw particle size to effect the releases of mineral matter from the coal, and recovering the ultra clean coal via a selective agglomeration process that employs pentane as the agglomerating agent. The pentane is removed from the recovered ultra clean product coal and reused. Less than 0.25 weight percent pentane remains with the product coal. The mineral matter and pyrite remain in the aqueous phase and are removed from process water by settling. This process is claimed to remove virtually all the pyritic sulfur and a significant quantity of the mineral matter from virtually any coal, while recovering over 95% of the fired coal Btu's in the product coal. OTISCA FUEL is formulated using the ultra clean product coal, water, dispersants, and stabilizers. A typical OTISCA FUEL formulation consists of 50% ultra clean coal, 1.5% dispersant, 0.05% stabilizer, and water.

In the proposed project, Otisca will address the manufacturing and utilization of OTISCA FUEL in Central New York (CNY) State industrial boilers as a direct replacement for coal, fuel oil, and natural gas. The proposed program will support the conversion of up to seven industrial boilers in the CNY area from their existing configuration, i.e., the burning of oil, gas, or high-sulfur coal, to one that allows the combustion of OTISCA FUEL. Together, the conversions will involve the consumption of about 40,000 dry tons of T-Processed coal as OTISCA FUEL over a period of one year. During the utilization of the fuel, Otisca will monitor each boiler facility for fuel quality, fuel consumption, combustion efficiency, and steam production as well as stack emissions including NO_2, SO_2, CO, CO_2, and particulates.

PROPOSAL NUMBER 47: SUMMARY PROJECT INFORMATION

Proposer:	Energy Partners, Inc.
Proposal Title:	Retrofit an Existing Industrial Boiler with TAS Coal Micronization System
Project Location:	Sauget, St. Clair County, IL
Technology:	Coal micronization
Types of Coal to be Used:	High-sulfur bituminous
Project Size:	6 tons/hr coal feed rate
Project Duration(s):	36 months
Offeror's Proposed Cost Share:	50.0%
Project Team Members:	Energy Partners, Inc. Monsanto Company The Babcock & Wilcox Company Peabody Holding Company, Inc. Illinois Department of Energy and Natural Resources

PROJECT SUMMARY

Proposal: 47

Offeror: Energy Partners, Inc.

Title: Retrofit an Existing Industrial Boiler with TAS Coal Micronization System

Project Summary:

The proposed project is for the purpose of demonstrating the TAS coal micronization system along with co-micronization of a sorbent, limestone, as an effective method for reducing SO_x emissions from coal-fired boilers. This process will allow coal to be utilized in oil/gas designed boilers. The project will utilize commercially available TAS mills and burners to retrofit a pulverized coal boiler which is currently redesigned for firing oil/gas. The proposed demonstration will burn high-sulfur coal/sorbent mixtures to produce the same SO_x level as the oil/gas firing.

The demonstration will be conducted on a 100,000-lb/hr boiler at Monsanto's Krummrich Plant in Sauget, Illinois, near St. Louis, Missouri. The participants in the project are Energy Partners, Inc., the proposer, Monsanto Co., the Babcock and Wilcox Company, Peabody Coal Co., and the State of Illinois. The size of the demonstration was chosen to allow the boiler to be retrofitted with a commercially-sized TAS coal micronization system. Two Illinois high-sulfur coals and five sorbents will be tested to determine SO_x capture. Testing of this process to date has found sulfur captures up to 90%. NO_x emissions reductions around 10% are expected by the proposer.

Due to the present relatively small size of the TAS mills, this technology, once successfully demonstrated, can retrofit many industrial boilers, process heaters, and kilns to provide the particular configuration necessary for firing with high-sulfur coals.

PROPOSAL NUMBER 48: SUMMARY PROJECT INFORMATION

Proposer:	Northern States Power Company
Proposal Title:	An Integrated Post-Combustion Environmental Control System
Project Location:	Becker, Sherburne County, MN
Technology:	Advanced scrubber with mineral recovery system
Types of Coal to be Used:	Subbituminous coal from Powder River Basin in Wyoming and Montana
Project Size:	750 MWe
Project Duration:	36 months
Offeror's Proposed Cost Share:	55.8%
Project Team Members:	Northern States Power Company Mountain States Mineral Enterprises, Inc.

PROJECT SUMMARY

Proposal: 48

Offeror: Northern States Power Company

Title: An Integrated Post-Combustion Environmental Control System

Project Summary:

The proposed project is for the purpose of demonstrating a new method of post-combustion flue gas treatment involving a modified wet limestone scrubber combined with electrostatic enhancements to decrease the sulfur dioxide emissions from power plant gases. Spent sorbent and fly ash discharged from the scrubber are then taken through a minerals processing operation where aluminum sulfate, alumina, iron, and a high quality industrial filler are recovered and marketed.

The 750-MWe scrubber demonstration will take place at Northern States Power Company's electric generating plant, Unit No. 2, in Sherburne County, Minnesota. Eight modules of an existing scrubber will be converted to the bubbler design. The electrostatic enhancements will be added to one of the modules in which the scrubber design will remove about 99% of the particulates, which consist mainly of spent limestone sorbent and fly ash; this material is then used as the feed to the minerals processing plant. The 1-ton/hr minerals processing demonstration plant uses conventional technology and off-the-shelf equipment. The product of the mineral processing plant are anticipated to be of high enough quality that they can be sold.

PROPOSAL NUMBER 49: SUMMARY PROJECT INFORMATION

Proposer:	Lignite Research Council of North Dakota
Proposal Title:	Fluidized-Bed Cogenerator with Gasification
Project Location:	Near Beulah, Mercer County, ND
Technology:	Circulating fluidized-bed combustion with cogeneration
Types of Coal to be Used:	Lignite
Project Size:	200 MWe
Project Duration:	(Not specified)
Offeror's Proposed Cost Share:	50.0%
Project Team Members:	(Not specified)

PROJECT SUMMARY

Proposal: 49

Offeror: Lignite Research Council, State of North Dakota

Title: Fluidized-Bed Cogeneration with Gasification

Project Summary:

The proposed project is to demonstrate the cogeneration of electric power and process steam. A commercial sized fluidized-bed cogeneration unit would be constructed and operated in conjunction with the Great Plains Gasification Plant. The facility would be located near Beulah, North Dakota.

The cogeneration unit will consist of a 200-MWe circulating fluidized-bed combustor boiler, a steam generator, and an electricity generator, which will be a stand-alone facility. Pulverized western coal (lignite) will be used as fuel.

There are several objectives for the demonstration plant. The size of the unit is to demonstrate economies of scale and an improved steam cycle, thereby allowing increased operation efficiencies. By allowing combustion gases to contact the circulating solids, the boiler design will reduce SO_2 and NO_x emissions. This reduction in SO_2 and NO_x emissions would further improve the air quality from the Great Plains Coal Gasification Plant.

In addition, the cogeneration plant will investigate the microbiological treatment of coal to remove the sulfur found in the lignite that is held as pyrite. This treatment requires finely ground coal to allow bacterial contact with the pyrite.

PROPOSAL NUMBER 50: SUMMARY PROJECT INFORMATION

Proposer:	En-R-Tech International, Inc.
Proposal Title:	The En-R-Tech Clean Coal Emission Program
Project Location:	Southern Illinois University at Carbondale, Jackson County, IL
Technology:	The En-R-Tech clean coal process
Type of Coal to be Used:	Bituminous
Project Size:	3 tons/hr coal feed rate
Project Duration:	24 months
Offeror's Proposed Cost Share:	(Not specified)
Project Team Members:	En-R-Tech International, Inc.

PROJECT SUMMARY

Proposal: 50

Offeror: En-R-Tech International, Inc.

Title: En-R-Tech Clean Coal Emission Program

Project Summary:

The proposed project is to demonstrate how fluid dynamics (i.e., particulate trajectories) can affect particulate loadings in exhaust gases passing through draft hoods. By reducing the velocity of these gases, it is possible to improve the capture rate of particulates and reduce most excess air in the combustion chamber.

The proposed demonstration facility is the powerhouse at the Southern Illinois University campus in Carbondale, Illinois. Exhaust gases from the boiler will be re-routed from its present location to the inlet side of the En-R-Tech system. The now slower moving gas stream can be treated with the fine mist sprayer to scrub out particulate matter from these gases. It is intended that all particulate matter caught by the mist will settle to the bottom of the tank, which will be designed with a downward slope to aid sludge withdrawal.

PROPOSAL NUMBER 51: SUMMARY PROJECT INFORMATION

Proposer:	City of Tallahassee, Florida
Proposal Title:	Arvah B. Hopkins Station Repowering Project
Project Location:	Arvah B. Hopkins Station Plant (west of Tallahassee), Leon County, FL
Technology:	Circulating fluidized-bed combustion
Types of Coal to be Used:	Eastern U.S. coal
Project Size:	250 MWe
Project Duration:	63 months
Offeror's Proposed Cost Share:	70.0%
Project Team Members:	City of Tallahassee, Florida Combustion Engineering, Inc.

PROJECT SUMMARY

Proposal: 51

Offeror: City of Tallahassee, Florida

Title: Arvah B. Hopkins Station Repowering Project

Project Summary:

The Electric Department of the City of Tallahassee, Florida, operates electrical generating and transmission facilities with a net summer system capacity of 460 MWe, of which 96.5% is oil/gas-fired. Its largest generating unit is the Arvah B. Hopkins Generating Station (Hopkins), a 235-MWe steam unit that operates on oil and gas fuels. The City of Tallahassee proposes to repower the existing oil/gas-fired boiler at Hopkins with a 250-MWe circulating fluidized-bed combustion (CFB) boiler. The proposed CFB boiler system will consist of one 1,787,655-lb/hr (superheater flow) CFB boiler rated at 1,940 psig, 1,005 °F throttle, and 1,005 °F reheat.

The 250-MWe CFB demonstration project represents a factor of 1.6 scale-up over the largest existing bubbling-bed AFBC unit, and a 2.5 scale-up over the largest existing CFB unit. The project is to be completed in 51 months, and after the test period the CFB will continue in commercial operation as part of the proposer's generating system.

PROPOSAL NUMBER 52: SUMMARY PROJECT INFORMATION

Proposer:	K-Fuel Partnership
Proposal Title:	Coal Processing Utilizing the K-Fuel Process to Produce High-Btu, Low-Sulfur Fuel from Low-Ranked Subbituminous Coal at Gillette, Wyoming
Project Location:	Gillette, Campbell County, WY
Technology:	Coal processing
Types of Coal to be Used:	Low-rank coal from the Fort Union mine
Project Size:	(Business confidential)
Project Duration:	(Business confidential)
Offeror's Proposed Cost Share:	(Business confidential)
Project Team Members:	K-Fuel Partnership (Koppelman Fuel Development Co. and S.A. Wilson, Inc.) Energy Brothers Technology, Inc.

PROJECT SUMMARY

Proposal: 52

Offeror: K-Fuel Partnership

Title: Coal Processing Utilizing the K-Fuel Process to Produce High-Btu, Low-Sulfur Fuel from Low-Rank Subbituminous Coal at Gillette, Wyoming

Project Summary:

The proposed project would demonstrate use of the K-Fuel process to upgrade low-rank coal from the Ft. Union mine to a product having a heating valve equivalent to bituminous coal. Two interrelated facilities would be utilized, both located near Gillette, Wyoming. The demonstration facility will be a prototype of a commercial unit. The second facility would be a "modification and development unit" to provide data for detailed design and operation of the larger unit.

Coal is slurried, pressurized, and processed in two rotary kilns operated in series. In the kilns, the coal comes in contact with a countercurrent flow of heated recycle gas. Tars and oils are recovered from the gas and used as a binder to make a briquetted K-Fuel product. Elemental sulfur is recovered from the off gas from the kiln and the cleaned gas is used as fuel in the process.

The process is applicable to high-moisture, low-rank feedstocks such as subbituminous coals, lignite, peat, municipal waste, and brown coal. Under the process conditions, these materials lose carboxylic groups as carbon dioxide, which, in turn, displaces much of the moisture in the feed coal while additional water is removed thermally. Removing the oxygen-containing groups changes the surface chemistry of the coal so that it becomes hydrophobic.

PROPOSAL NUMBER 53: SUMMARY PROJECT INFORMATION

Proposer:	Cool Water Coal Gasification Program
Proposal Title:	Cool Water Coal Gasification Extended Demonstration and Development Program
Project Location:	Daggett, San Bernardino County, CA
Technology:	Integrated gasification combined-cycle
Types of Coal to be Used:	U.S. eastern and western bituminous, 0.3-4.0% sulfur
Project Size:	55 tons/hr maximum coal feed rate Products: 50-100 tons/day methanol and 125 tons/day process slag
Project Duration:	48 months
Offeror's Proposed Cost Share:	62.4%
Project Team Members:	Cool Water Coal Gasification Program Southern California Edison Company Texaco, Inc. General Electric Company Bechtel Power Corporation EPRI Japan Cool Water Program Partnership ESEERCO Ohio Coal Development Office California Air Oval District California Energy Commission Illinois Department of Energy Chem Systems, Inc. Air Products and Chemicals, Inc.

PROJECT SUMMARY

Proposal: 53

Offeror: Cool Water Coal Gasification Program

Title: Cool Water Coal Gasification Extended Demonstration and Development Program

Project Summary:

Cool Water Coal Gasification Program (CWCGP) located in Dagget, California, has successfully operated a 103-MWe (net) commercial-size module of an integrated coal gasification combined-cycle (IGCC) power plant since 1984. This includes a 1,200-tons/day coal gasification plant using the Texaco gasification process. CWCGP proposes to conduct an extended 4-year demonstration and development program at the same facility.

A key element of the continued demonstration plan is 1 year of operation on high-sulfur eastern U.S. coal. CWCGP believes previous high-sulfur coal operation was too brief to establish optimum design parameters including metallurgy selection. Since IGCC plants will probably find greatest application on high-sulfur coals, it is critical to have confidence in materials selection.

Methanol is used as a chemical feedstock and can be used as a transportation fuel to reduce pollution (of interest in the Los Angeles basin) and as a clean utility peaking fuel. IGCC plants can produce the methanol continuously or during off-peak periods, CWCGP will produce methanol during the last 2 years of the 4-year extended demonstration. CWCGP also plans to demonstrate the use of methanol in the existing gas turbine.

Coal typically contains 5-15% of inert mineral matter which ends up as gasifier slag from a Texaco IGCC plant. CWCGP plans to produce lightweight aggregate from its full 125 tons/day of slag production and further develop the existing markets.

PROPOSAL NUMBER 54: SUMMARY PROJECT INFORMATION

Proposer:	*Helipump Corporation*
Proposal Title:	Innovative NO_x and SO_x Control with the All Solid-State Electrocatalytic Modular IGR Process
Project Location:	Cleveland, Cuyahoga County, OH or Buffalo, Niagara County, NY
Technology:	NO_x and SO_x capture in flue gas/solid-state electrocatalytic module
Types of Coal to be Used:	Ohio high-sulfur coal
Project Size:	1,000 ft^3/min
Project Duration:	48 months
Offeror's Proposed Cost Share:	50.0%
Project Team Members:	Helipump Corporation IGR Enterprises, Inc.

PROJECT SUMMARY

Proposal: 54

Offeror: Helipump Corporation

Title: Innovative NO_x and SO_x Control with the All Solid-State Electrocatalytic Modular IGR Process

Project Summary:

The proposed project is for the purpose of demonstrating that the IGR process can simultaneously control sulfur and nitrogen oxides for coal-fired boilers at a fraction of the cost of currently available control technologies. The IGR process is an all solid-state flow-through electrocatalytic technology composed of modules than can be scaled up. This conceptually simple process has no moving parts and converts the nitrogen oxides and sulfur oxides in flue gas into elemental nitrogen, sulfur, and oxygen. The process does not require any sorbents or water and does not produce any waste products other than sulfur which can be recovered as a salable commodity.

The demonstration will be located either at the Electric Power Research Institute (EPRI) High-Sulfur Test Facility near Buffalo, New York, or an alternate site in Ohio hosted by Centerior Energy Corporation. The goal of the proposed demonstration is to scale up the IGR technology from the current 10-acfm unit being built under a present contract with PETC to a 100-acfm "Engineering Test Module" to be constructed at the proposers laboratory at Case Western Reserve University and then to a 1,000-acfm "Proof-of-Concept Process Demonstration" at the above utility site. These latter two units and supporting research are included as part of the proposed project. The demonstration will be conducted by Helipump Corporation in cooperation with IGR Enterprises, Inc., and the Ohio Coal Development Office.

PROPOSAL NUMBER 55: SUMMARY PROJECT INFORMATION

Proposer:	Carbonic International, Inc.
Proposal Title:	Flue Gas Separation Plant
Project Location:	Orange County, FL
Technology:	Flue gas separation
Types of Coal to be Used:	(No coal types specified)
Project Size:	(Not specified)
Project Duration:	(Not specified)
Offeror's Proposed Cost Share:	(Not specified)
Project Team Members:	Carbonic International, Inc.

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PROJECT SUMMARY

Proposal: 55

Offeror: Carbonic International, Inc.

Title: Flue Gas Separation Plant

Project Summary:

The proposed project will address the issue of CO_2 and its relation to the "greenhouse effect." A 300-tons/day separation plant will be constructed. The feasibility and economics of capturing CO_2 emissions from a smoke stack and effects upon atmospheric heating and acid will be investigated. The proposed location will be Orange County, Florida.